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Back Injuries

Proceedings: Bureau of Mines Technology Transfer Symposia, Pittsburgh, PA, August 9, 1983, and Reno, NV, August 15, 1983

Compiled by James M. Peay

UNITED STATES DEPARTMENT OF THE INTERIOR

(United States. Bureau of Mines)

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Compiled by James M. Peay[1]

ABSTRACT

These proceedings consist of papers presented at two Bureau of Mines Technology Transfer symposia on reducing back injuries in the mining industry. The symposia were held in August 1983 and covered a wide range of topics related to a more fundamental understanding of factors that lead to back injuries and approaches for reducing the frequency and severity of such injuries.

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INTRODUCTION

Back injuries constitute the largest single category of lost-time accidents in the mining industry. U.S. Department of Labor [Health and Safety Analysis Center (HSAC)] data for 1981 indicates there were 37,017 accidents in the mining industry of which approximately 25 pct or roughly 9,254 incidents involved back injuries. Back injuries of the most severe nature, i.e., strains, sprains, and dislocated disks accounted for 5,458 incidents or approximately 15 pct of all mining injuries.

In addition, this category of injury accounts for more lost workdays than any other single type of injury. For example, 40 pct of the lost-time back injuries incurred by underground coal miners during 1981 resulted in the miner missing more than 4 weeks of work. When the number of lost workdays per back injury incident is compared with other types of mining injuries, statistics indicate that on the average, those workers experiencing back injuries are off the job approximately 6 days longer. Thus, back injuries not only constitute the single largest category of mining injuries, but also lead in degree of severity as reflected in lost workdays.

Back injuries, therefore, represent not only a tremendous economic cost to coal companies, to miners and their families, and to society, they also represent a tremendous amount of human suffering. Data and expert optinion are in agreement that intensified efforts and new approaches to reducing back injuries are called for.

As pointed out by Robert H. Peters' paper in these proceedings, there are many good reasons to believe that the mining environmental conditions and current work procedures, which involve considerable manual materials handling tasks, pose relatively unique barriers to preventing back injuries. Compared with most other types of industrial settings, many mines, especially underground operations, require considerable manual lifting of heavy materials. Also, compared with most other types of industrial settings, many underground coal mines have less than desirable illumination, are wetter, and have constricted work spaces. Illumination and water problems can result in back injuries caused by slipping on wet or muddy surfaces or by tripping over things that cannot be easily seen. The thickness of many mineral seams also prevents miners from performing work while standing erect, forcing miners to perform heavy work while in stooped or kneeling positions, thus placing significantly more stress on their backs than other industrial workers who can perform lifting activites while standing erect.

Training miners to cope with existing work conditions has been the traditional approach to reducing back injuries, however this method has many deficiencies, as reflected in the continuing high frequency and severity rates. While improved training should be continued, newly developed selection procedures and extensive job redesign based on biomechanical and ergonomic studies appear to offer the greatest potential for future positive impact. Many of the papers contained in these proceedings, therefore, focus on assessment and selection of workers who are most capable of performing heavy lifting tasks and on analysis and design of mining jobs to eliminate many hazards that eventually lead to back injuries.

MATERIALS HANDLING METHODS AND PROBLEMS IN UNDERGROUND COAL MINES

By Richard L. Unger[1] and Daniel J. Connelly[2]

ABSTRACT

Materials handling accidents are the leading cause of nonfatal injuries in underground coal mines in the United States. The Bureau of Mines has sponsored research into the problems associated with materials handling in underground coal mines. This paper provides descriptions of the methods, examples of activities, flow paths of materials, problem areas, and accident analyses of materials handling operations reported in Bureau of Mines research studies.

INTRODUCTION

Annually, materials handling is the leading accident classification in underground coal mines in the United States. In 1980, materials handling accidents accounted for 34% of the 15,075 nonfatal days-lost accidents in underground coal mines.

In order to identify the various factors that characterize the materials handling problem, several analyses are necessary. Bureau of Mines sponsored research projects[3] have provided a better understanding of materials handling accidents in underground coal mines. The information reported in this paper is a result of those research efforts. The descriptions of materials handling methods, flow patterns, commonly handled materials, problems of mine environment and personnel, and accident analyses that are presented define the hazards associated with materials handling in underground coal mines.

BREAKDOWN OF THE OPERATING ENVIRONMENT

Manual handling of materials in an underground coal mine can be described as the performance of actions on items in various operating environments. The operating environments can be described by the associated mine activities, location, space limitations, and usage. A practical division of the operating environments has been defined by handling functions which describe the general purpose of the activities.[4] These handling functions are

1. Production end use.[5] This function relates to the handling of items during their end use at the working face. Some work activity examples are

   Erecting temporary curtains for ventilation.

   Rock dusting.

   Roof bolting.

   Erecting roof timbers.

[1]Civil engineer.

[2]Safety specialist.

Both authors are employed by the Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

[3]Diaz, R. A., and A. D. Chitaley. System for Handling Supplies in Underground Coal Mines ongoing BuMines contract H0188049; for inf., contact G. R. Bockosh, TPO, Pittsburgh Res. Center, Pittsburgh, PA.

Foote, A. L., and J. S. Schaefer. Mine Materials Handling Vehicle (MMHV) (contract H0242015 MBAssociates). BuMines OFR 59-80, 1978, 308 pp.; NTIS PB 80-178890.

[4]First work cited in footnote 3.

[5]The end use handling associated with section move, mine maintenance, and equipment maintenance is included in the respective functions. End use handling associated with the production handling function is classified as a separate function.

2. Production supply. This function relates to the handling of materials from the surface yard to locations near the working face. It excludes the end use handling. Work activities in this function are directly related to production. Some examples of work activities are

Transporting rock-dust bags.

Transporting roof bolts.

Transporting timbers.

3. Section move. This function relates to the handling of materials from the surface yard to the section being moved. It also includes the handling during the process of moving a mining section. Some examples of work activities are

Moving haulage belts.

Tearing up and re-laying rails.

Transporting cables.

Moving air lines, compressors.

Longwall face supports.

4. Equipment maintenance. This function relates to the handling of materials from the surface yard to the point of use. It also includes final handling activities during maintenance of mine equipment. Some examples of work activities are

Extracting motors from continuous miners.

Replacing of extinguisher canisters.

Replenishing transformer oil, hydraulic oil.

5. Mine maintenance. This function relates to handling of materials from the surface yard to the point of end use for mine maintenance. It also includes final handling during scheduled and unscheduled mine maintenance. Mine maintenance activities include the maintenance of roof, floor, ventilation, pathways, rail track, and the like. It excludes equipment maintenance activities, but includes those activities on equipment which form part of the mine installation. Some examples of work activities are

Erecting stoppings for ventilation.

Setting props and crossbars for roof support.

Laying rail.

Upgrading track.

Table 1 gives examples of materials associated with various handling functions for further understanding of the work activities associated with each function. Each of the handling functions can be categorized by the type of materials handled, the usage frequency, and the flow path. The flow path indicates the path followed by the materials in reaching the end use. The flow paths and the typical materials moved in each of the handling functions are described in appendix A. The handling functions will be used later to analyze the accidents associated with materials handling.

TABLE 1. - Examples of materials handled in various handling functions[1]

Materials handled	Handling functions[2]
Roof and rib support items: Roof bolts, roof bolt plates, expansion heads, half headers, timbers, steel beams, hydraulic jacks, crib materials, cement, sand.	Production end use, production supply mine maintenance.
Fire protection items: Rock dust, extinguisher cannister, foam tank.	All handling functions.
Coal handling equipment items:	
Belting, jacks, conveyor parts, rollers, stands.	Production end use, production supply, equipment maintenance, section move.
Shuttle cars, face equipment................	Equipment maintenance, section move.
Vehicle maintenance items: Tires, cans of hydraulic oil, grease, and brake fluid, motors, handtools and power tools, welding equipment.	Production supply, equipment maintenance.
Air supply items: Air lines, compressors, hoses, line fittings.	All handling functions.
Water supply items: Hoses, pipes, pumps, line fittings.	Production end use, production supply, section move, mine maintenance.
Ventilation items: Tubing, brattice, motors, brackets, hardware.	All handling functions.
Power supply items: Wire and cable spools, motors, transformers, cans of transformer oil, J hooks, motors, meters, power units, trailing units, trailing cables and connectors, breaker and switching panels.	Do.
Personnel support items: Food and water containers, toilets, first aid kits, handtools.	Production end use, production supply, section move.

[1]Based on classifications in a study of 27 mines reported in the second work of footnote 3.

[2]The end use handling associated with section move, mine maintenance, and equipment maintenance is included in the respective functions. End use handling associated with production handling function is classified as a separate function.

CURRENT PRACTICES IN MATERIALS HANDLING OPERATIONS

Many methods exist for handling materials among underground coal mines. Moreover, different methods may be used for different materials within the same mine. Each mine, however, seems to have an established set of procedures for handling production, mine maintenance and equipment maintenance materials, and for advancing or retreating a section.

HANDLING OF PRODUCTION AND MINE MAINTENANCE SUPPLIES

In terms of tasks and worker activities, production supply and mine maintenance are closely related. For this reason the discussion of these functions has been combined.

Production and mine maintenance materials are nearly always handled by a set of routine procedures. A typical cycle of events in this materials handling process could include the following:

Transferring materials from commercial carriers to a surface storage area, and loading them on supply trips in their existing packaged form to be transported to the section.

Breaking the bindings of materials in packaged form and transferring individual items or small bundles of items from the supply trip to the section storage area.

Transferring the materials from the section storage area to an area near the working face.

Transporting the individual items for their end use.

A general discussion of production and mine maintenance handling methods follows.

Handling on the Surface

Materials usually arrive at the mine by truck or railroad. Most often they are packaged on pallets or in strapped bundles. It was noted that some mines received roof bolts in packages of 10 with a number of packages strapped to a pallet.

Forklifts, cherrypickers, front-end loaders, and cranes are sometimes used to help unload and stack the materials in the surface storage area, but all mines studied used some degree of manual handling at the surface. Some materials are loaded in their packaged form, though it is more common to have individual items or small bundles loaded manually into the vehicle for the trip into the mine. Some mines perform bulk handling of rock dust and oil. In these cases, the surface yard will have bulk storage facilities for these items after they have been received from the supplier. Rock dust may be pneumatically transferred into a rock-dust bin from a truck or railroad car. Hydraulic oil is pumped into a bulk tank, or the mine may have an "oil house" where it cleans, empties, and fills containers to be transported to the section.

Typically, section supervisors will generate lists of their supply needs. A surface crew will take the list from each section and assemble a supply trip. In some mines, the supply function is a scheduled effort that tries to anticipate production and mine maintenance needs rather than responding to demand. The supply trip will deliver a scheduled amount of supplies in accordance to the linear advance expected from the section. In large mines, it is common for the supply trips to be loaded on the first shift and hauled into the mine on the third. The supply logistics are less formal for the smaller mines of one or two sections.

Transport to the Section

The methods of transporting supplies to the section change with the items to be handled. Solid supplies, such as roof bolts, posts, blocks, and crossbars, are transported as individual items or pallets by means of mine cars or rubber-tired vehicles. Large volume liquid and granular supplies, such as rock dust,

hydraulic oil, and water, are put into containers and transported on vehicles or handled in bulk form.

There are several types of solid items with different weights and sizes involved in the production and mine maintenance supply function. Table 2 outlines a typical list of items and average use per day per section.

TABLE 2. - Description and usage of typical supply items

Supply	Weight, lb	Av. use
2- to 12-foot plates, roof bolts, and shells..........	4- 12	123
Rock dust sacks.............	50	75
2- by 6-in to 6- by 8-in, 1- to 16-ft lengths of timber, boards, and headers........	8-270	61
16- by 8- by 4- or 6-in stopping blocks............	27- 65	52
8- to 13-ft header steel....	10- 16	25
Bit:		
Continuous miner..........	<1	18
Roof drill................	<1	16
5-gal oil container.........	40	15
4- to 10-in diam, 3- to 15-ft round timber posts......	34-320	15
1- to 6-ft crib block.......	20- 60	12
Mortar mix sacks............	90	3
75-ft brattice roll.........	60	<1

[1]Based on yearly supply consumption of 27 mines reported in the second work of footnote 3.

A major difference in transport to the section involves the use of area storage. A few mines use intermediate storage locations, each of which serves several working sections. This method requires a transfer from the supply trip to stacks, usually along the rib of the supply entry, and then another transfer to a vehicle for haulage into the section.

Most mines transport directly from surface storage to the section without an intermediate storage area. There are four methods of transport in common use

1. Rubber-tired haulage in drift mines where the distance from surface to section is short (less than 1 mile) using battery-powered vehicles, scoops, and/or tractor-trailer combinations.

2. Rail haulage with a track laid in a section heading as far as the tailpiece using railcars pulled by a motor.

3. Rail haulage with track not extended into the section and transferring directly to battery-powered vehicles.

4. Rail haulage with track not extended to the section using rubber-tired or railcars until the end of the track and then converting to rubber-tired haulage by battery-powered tractors.

5. Another method, though not in common use, is to reverse the conveyor belt to handle materials; this requires manual handling at the loading and unloading point.

Many methods exist for handling bulk materials, such as rock dust and hydraulic oil. In the case of rock dust, the need to handle bagged rock dust has been practically eliminated by the use of one of the following bulk transportation methods:

1. Rock dust is pneumatically piped into a rock-dust car at the section. In smaller mines, it is piped directly to the face.

2. Rock dust is fed by gravity through a borehole or through a casing suspended from an air shaft into a rock dust car and then hauled to the section.

3. Rock dust is unloaded from a bin into a rock dust car at the surface.

Two methods of handling bulk oil include having it flow by gravity from an oil tank at the surface into an intermediate storage area, or using 55-gal drums transported by supply vehicle to the section.

Handling in the Section

Once the railcar or other supply vehicle has arrived in the section two or three crosscuts from the working face,

items are usually unloaded and stacked. In some mines, the vehicles are parked at the section and the materials are used directly.

If the supply vehicle is left in the section, there is less handling of materials; however, mines vary in their willingness to leave cars in the section for two reasons. First, leaving the car takes up room and makes switching difficult, and second, more supply cars are required.

Haulage of supplies from section storage to end use is accomplished several ways

Manual carrying.

Battery-powered vehicles such as scoops, tractors, and personal carriers.

Face equipment, such as roof bolters, shuttle cars, and rock dusts.

When oil is transported in bulk to the section, the usual procedure is to fill 5-gal containers and carry them to final use.

HANDLING OF EQUIPMENT MAINTENANCE MATERIALS

The handling of equipment maintenance materials usually follows very undefined paths. Some components are kept in surface storage, but more likely they will be found in section storage locations. These locations vary from a small underground shop with an overhead hoist to storage stacks in a crosscut along a supply route. Some frequently used items such as shuttle car wheels and hydraulic hoses, can often be found in section storage.

When a machine component is needed, it is generally transported by the quickest means possible to minimize downtime. Problems are frequently encountered owing to the weight of the item (sometimes over 2,000 lb). These materials are usually handled with a combination of manual handling and mechanical devices such as a machine-mounted winch, come-along, or jack.

HANDLING OF SECTION MOVE SUPPLIES

The advance of the section calls for the addition of conveyor sections, electrical cable, and track, plus the transport of equipment, such as a tailpiece, belt feeder, or power boxes. While these materials usually follow the conventional supply route, their size and weight require special handling. This is accomplished using a combination of manual handling and powered equipment.

For longwall sections, specially designed lift-transporting devices have been developed to handle roof supports which present a problem owing to their weight (10,000-lb range) and distances they must be moved.

MINE ENVIRONMENT AND MATERIALS HANDLING METHODS

There are many environmental factors that have an effect on a mine materials handling method. These include

Mine size.

Portal; drift, slope, shaft.

Mining method; continuous, conventional, longwall.

Coal haulage; belt, rail.

Seam height.

Stage of development; advance, retreat, rooms.

The size of the mine plays a role in determining the equipment available for materials handling. Some mines are small enough to use battery-powered scoops or tractors to haul materials from the surface to the section. Large mines are more likely to use forklifts and cranes

for surface handling because they have higher utilization of such equipment.

The type of portal effects the difficulty of transporting the materials into and out of the mine. Transportation into a drift mine is usually the easiest since a locomotive can often run in and out of the mine. At slope mines, it is common practice to lower the supply trip into the mine using a hoist. The shaft mine poses the most problems since a train of cars cannot be transported into the mine. In some cases, they can be lowered one car at a time by hoist; or where cars cannot be hoisted, materials must be doubly handled.

The mining method has the largest effect on the types of materials that are handled. Conventional mining involves essentially the same materials handling methods as continuous mining except for the special requirements for handling explosives. However, longwall mining has radically different requirements. Materials, such as roof bolts, rock dust, and stopping blocks, are used only on a limited basis for development. The description for handling equipment maintenance materials and section move could serve as the general pattern for longwall sections, except that in longwall mining the section move is a massive operation.

The method of coal haulage does not appear to have a large impact on handling methods because track is generally laid for personnel and supply movement even in mines with belt haulage. Probably the largest factor influencing the movement of materials is the scheduling problems encountered between supply trips and coal haulage on the main line track

Seam height has a large impact from several aspects. A high-seam mine operation is better able to lay track up to a section because it is not faced with the costs of cutting roof or bottom to provide height clearance. In low mines, problems are encountered when loading supplies in and out of supply cars because of limited clearance between the sides of the car and the roof. This same problem makes it impossible to use available overhead lifting devices. Another problem results because manual lifting and carrying must be done while bending over, which is extremely strenuous to the back.

The stage of mine development has an impact mainly on the materials used. Material usage changes significantly between advance and retreat mining. For instance, in retreat mining, more timber is used and new stoppings will not be erected. The major problem with retreat mining is associated with recovery of materials. As the section retreats, materials such as conveyor sections, track, water pipe and electrical cable, must be pulled out of the section and stored.

PROBLEM AREAS IN THE PRESENT MATERIALS HANDLING SYSTEMS IN UNDERGROUND COAL MINES

Interviews with mine operators and equipment manufacturers have indicated a general awareness of materials handling problem areas such as accidents, supply function, labor costs, and production delays due to maintenance and production supply system breakdowns.[6] The production materials handling function supports most other activities in the mine and is affected by its interaction with other operations. Daily supply items such as roof bolts, timber bolts, and concrete blocks, are needed at various locations at different times. The movement of mine maintenance and equipment maintenance materials, such as replacement motors, are vital to keeping production going. Section move, though not as common an occurrence, poses special hazards owing to the size and weight of the items being handled.

Meeting these needs requires the movement and handling of materials by most mine personnel. Their activities are based on the quantities of items

[6]First work cited in footnote 3.

required, times when they are needed, physical characteristics of the items, transfers between transport equipment and storage, availability of transport and other handling equipment, communications systems among the supply personnel, information exchange between the supply personnel and other miners, and the predictability of supply needs at various locations underground. The following sections discuss problems related to the above factors.

PERFORMANCE OF HAZARDOUS MANUAL ACTIONS

Manual handling of items is very common in underground coal mines. Typically, materials are loaded and unloaded from vehicles, placed in storage, carried, or simply held unsupported. Such manual handling occurs in support of mine operations such as production, mine maintenance, equipment maintenance, and section move. Manual actions directly associated with accidents can be grouped as follows:

Stationary actions (transfer)

Lifting or lowering without support (supply item is supported manually).

Pushing or pulling with support (supply item is on floor or surface of a vehicle).

Holding without support (supply item is held manually).

Walking actions (transport)

Carrying without support (supply item is held manually).

Pushing or pulling with support (supply item is on floor, skid, or on surface of a vehicle).

End use actions

All actions connected with the final application of supply items and not separately classified as stationary or walking actions.

ACCIDENT ANALYSIS OF HANDLING FUNCTIONS AND ACTIONS

Accident data used were obtained in a study of 27 mines representative of the coal mining industry profile.[7] These data were taken from mine accident records for 1973.

In the 27 mines sampled, a total of 269 materials handling accidents took place. A total of 771 days were lost because of these accidents. The total hours worked were 10.356 million and total coal production was 15.121 million tons. Accident data were analyzed for the handling functions and actions defined earlier. Accident frequencies, days lost, and severity were calculated for various handling functions and actions and are presented in appendix B.[8] The following paragraphs highlight the findings of this analysis.

The reported accident data were analyzed for frequency and severity with reference to manual actions and handling functions. The following significant observations resulted from the analysis:

The production supply and mine maintenance functions are highly hazardous supply environments.

They account for 60% of the accidents.

They account for 76% of the days lost.

Accident severity (6.26) is the highest in the mine maintenance function.

Accident severity (3.25) is also high in the production supply function.

Stationary manual actions in the production supply and mine maintenance functions are the largest contributors to the total accidents.

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[7] Second work cited in footnote 3.

[8] See appendix B for definitions of frequency, days lost, and severity.

Lifting and lowering without support is a highly hazardous manual action in materials handling. It accounts for 59% of all accidents and 54% of days lost.

Manual carrying without support is a hazardous action with high accident severity (4.11).

INEFFICIENT UTILIZATION OF SUPPLY LABOR

In general, supply-related personnel are underutilized in that their productive time is less than half of the working shift. Considerable time is spent in traveling to and from work areas, waiting, returning empties, and the like. In some mines, a large fraction of the time is lost owing to early quitting, late starting, and traffic conflicts. Some identifiable factors related to this problem include

Performance standards have not been developed, therefore, staffing and scheduling or performance control is based almost entirely on experience and guesswork.

Staffing of the supply function is based on past history, experience, and anticipation of peak loads, which results in overstaffing.

For some items the usage quantity, place, and time are predetermined. Yet a large number enter the mine on an as- and when-needed basis. The lag time between a supply requisition by the section or mine supervisor from the surface yard and the actual delivery of the item encourages the supervisor to overstock supplies in advance. Very few supply scheduling plans exist.

In general, predetermined routing of items to the working section does not exist and is rarely followed when it does. This creates hazards and makes supervision difficult.

Communications between personnel handling material is difficult because of noise and poor visibility.

Good information exchange between the section and mine supervisor and the supply crew do not normally exist.

PERSONNEL PROBLEMS

Several personnel problems were identified as reducing the efficiency of materials handling operations, as well as increasing the possibility of an injury in the performance of manual handling tasks.

Job bidding in union mines gives the workers an opportunity for higher wages and job advancement. This generally results in junior, more inexperienced personnel staffing the supply function or doing other manual labor.

Stretching physical limits and capabilities in manual handling of materials often result in injuries to personnel with inadequate physical capability in an effort to meet job requirements.

Very little formal safety training is obtained by supply personnel because most of the training is "on the job." Also, there is little training given on techniques for manual handling of materials in an underground environment.

WEIGHT OF SUPPLY ITEMS

Table 2 outlines the size and weight ranges and average daily section usage of some common supply items. Many supply items such as rails, timber, headers, stopping blocks, crib blocks, bags of rock dust or mortar mix, and the like, are of considerable weight. The manual handling of such supply items in a low roof, poor footing environment increases the probability of accidents and handling time, even though they are usually handled by more than one person per item. In general, very few attempts have been made at weight reduction of supply items. A known exception is the recent use of fiberglass beams by some mines. These beams are considerably lighter than timber.

Figures B-5 and B-6 of appendix B give frequencies and severities for accidents occurring while handling supply items of various weight groups. The accident data indicate the following:

Most of the accidents occur while handling supply items in the 1- to 100-lb weight group.

Typical supply items in this weight group are roof bolts, short timber, 5-gal oil containers, rock dust or mortar mix bags, belts, and stopping block.

The 1- to 100-lb weight group accounts for the majority of days lost.

Accident severity is very high for the 200- to 500-lb weight groups taken together.

Typical supply items in this weight group are electric motors, equipment components, haulage rails, PVC and steel pipes, pumps, timber, and large oil drums.

HAZARDOUS ENVIRONMENTAL CONDITIONS

The underground mine environment is considerably more hazardous and difficult to work in as compared to most surface environments. Such conditions not only increase the probabilities of accidents, but also reduce the rate of manual work. Some examples of hazardous handling operations due to the environment are as follows:

Bending or sitting on folded legs is common in mines of low roof height. Holding without support, lifting, or carrying weight under such conditions can result in back injuries. This cumbersome position causes worker fatigue and increases the potential for dropping loads.

Poor maintenance of the mine bottom results in slippery and uneven footing. Manual handling actions performed under such conditions increase the potential for accidents.

SUMMARY

Materials handling accidents have been identified as a significant problem area in underground coal mines. Bureau of Mines research has provided a better understanding of the numerous factors contributing to materials handling problems.

In this paper, descriptions and examples of current materials handling methods and problems in underground coal mines have been presented, as reported in Bureau of Mines research studies. Materials handling activities have been defined by the various mining operations which describe their general purpose. These materials handling functions are: Production End Use, Production Supply, Section Move, Equipment Maintenance, and Mine Maintenance.

A survey of a representative sample of underground coal mines[9] has resulted in a description of the methods, practices, flow paths, and items typical of materials handling activities. In addition, several specific problem areas associated with materials handling in underground coal mines, such as manual handling actions accidents, inefficient use of labor, and hazardous environmental conditions, have been discussed. In summary, this paper has provided an overview of the methods and problems of materials handling in underground coal mines.

[9]Second work cited in footnote 3.

APPENDIX A.--FLOW PATHS AND MATERIALS FOR VARIOUS MATERIALS HANDLING FUNCTIONS

Figures A-1 through A-5 illustrate flow paths of materials in various operating environments defined by the handling functions. Only the major items of the handling function have been listed in each figure. The flow paths also show locations at which manual transfer, transport, and end use actions are performed on the materials.

APPENDIX B.--ACCIDENT ANALYSIS

Accident data collected in a study of 27 mines has been analyzed in this appendix. Accident frequencies, severity, and days lost have been calculated for various handling functions, manual hazardous actions, and weight groups of items. Figures B-1 through B-6 illustrate the results of these analyses. In the following sections, accidents are further discussed in terms of various handling functions. Some definitions used in these discussions include:

Frequency--The number of accidents for a particular handling function.

Severity--Frequency divided by the number of days lost for a particular handling function.

Days lost--Actual days lost from work.

PRODUCTION SUPPLY AND MINE MAINTENANCE FUNCTIONS

Since most of the materials used and manual actions are similar for these functions and since their activities are closely related, the accident data for these two functions have been combined.

Sixty percent (160 out of 269) of all manual handling accidents take place in the production supply and mine maintenance functions. The number of days lost owing to accidents in these two functions together account for 76% (588 out of 771 days lost). The severity of accidents in the mine maintenance function is the highest, 6.26 days lost per accident. The severity in the production supply function is also high, 3.15 days lost per accident.

Most of the accidents in these functions are related to stationary actions (38% of 269). Walking actions account for the next largest number of accidents in these functions (18% of 269).

PRODUCTION END USE FUNCTION

Roof jacks, crossbars, round posts, and trailing cables account for the majority of the accidents in this handling function. (Refer to table B-1.)

Stationary actions account for 77% of the accidents in this function, while walking actions relate to 23%.

Cable handling poses a handling problem different from the other materials used in this function. At intersections, the cable has to be lifted and hung from a hook anchored to a roof bolt. It also has to be pulled in advance of tramming equipment to prevent damage by tramming over the cable. The production end use function accounts for 30% (out of 269) accidents, but only 5% of the total 771 days lost. The accident severity is considerably lower than other functions, 1.17 days lost per accident.

TABLE B-1. - Number of accidents classified by manual actions in the production end use function

Item	Weight, lb	Accidents	
		Stationary	Walking
6- by 6-in by 5- to 8-ft (closed) roof jack........	50- 70	3	4
6- by 8-in by 10- to 14-ft crossbar	160-225	5	0
6-in-diam by 5- to 8-ft round posts.	48- 76	3	2
2- to 3-in-diam trailing cable...	[1]5- 10	4	0
Other items.......	NAp	8	1
Total........	NAp	23	7

NAp Not applicable.
[1]Per foot.

SECTION MOVE FUNCTION

A major move of a production unit from one section to another is infrequent, occurring from one to three times per year. Most of the handling actions and materials are similar to other functions. A number of manual handling actions are involved during the section move operation. Handling of rail, belt, and belt rollers cause the majority of accidents in this function (table B-2). In some mines,

TABLE B-2. - Number of accidents classified by manual actions for some materials in the section move function

Item	Common usage	Weight, lb	Accidents	
			Stationary	Walking
40- to 85-lb rail, 20- to 39-ft length.	Coal, supply haulage..	266-1,100	9	6
Belt roller, 4-in-diam by 36-in length to 6-in-diam by 42-in length.	Return (bottom) idler.	40- 50	4	1
Belt, 36- and 42-in width....	Coal haulage..........	NA	4	0
Rail tie, 8 by 6 by 72 in....	Support for rail......	90- 100	1	1
Belt chain, 8 by 9 by 52 in..	Carrying (top) idler..	20- 25	1	0
Total..................	NAp....................	NAp	19	8

NA Not available. NAp Not applicable.

rails are manually rolled off a supply car and then manually dragged into place, which is a hazardous practice. In other mines, the rail is attached by a chain to a scoop, battery tractor, or the like, and is pulled out of the supply car and then pulled into place by the transport vehicle. This handling practice, too, is considered hazardous.

Section move accounts for 13% (out of 269) accidents, with 7% (out of 771) days lost.

EQUIPMENT MAINTENANCE FUNCTION

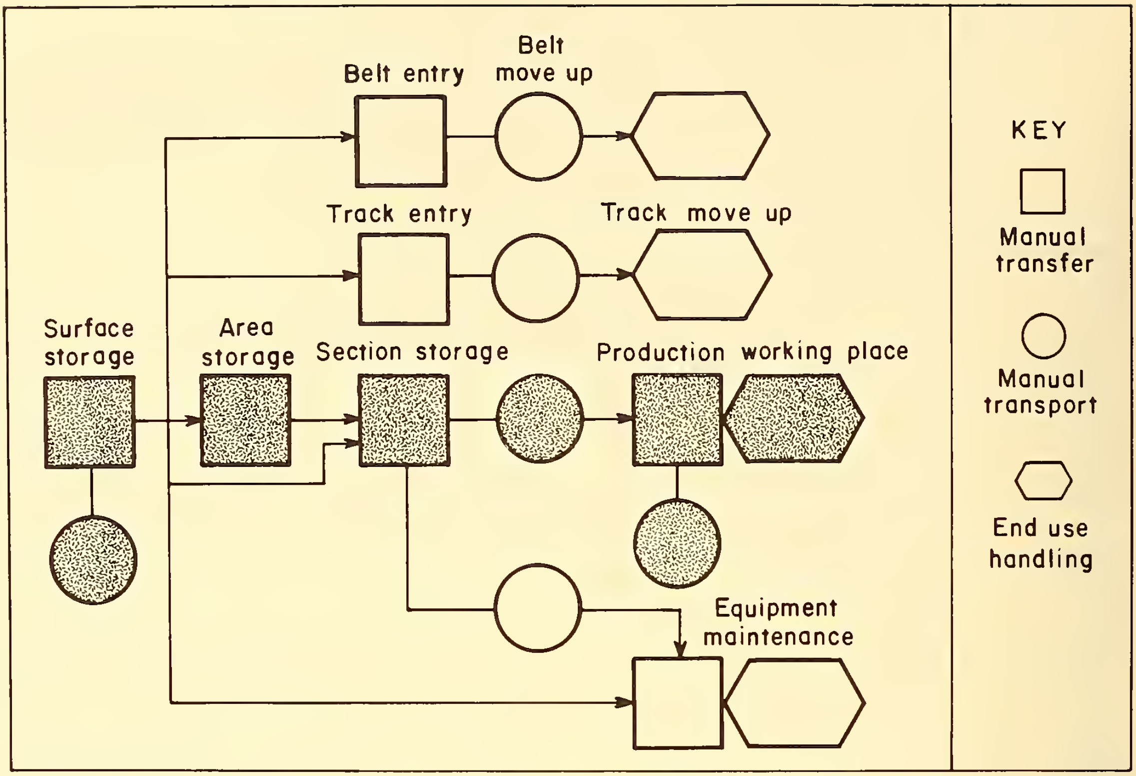
This function accounts for the next largest number of accidents, 16% (out of 269) and days lost, 12% (out of 771), as compared with production supply and mine maintenance functions. Stationary actions performed during removal and replacement of heavy equipment parts, such as motors, rubber tires on haulage vehicles, and the like, account for most of the accidents in this function.

Most of the items in this function are in the 50- to 200-lb range and are usually handled by one to four miners. Another major source of accidents is the manual handling of 5-gal cans of hydraulic oil, tool boxes, and welding gas bottles. Generally, tool boxes weigh up to 100 lb and require two miners to lift or carry them.

Table B-3 gives the accident frequencies for various materials and hazardous manual actions for the equipment maintenance function.

TABLE B-3. - Number of accidents classified by manual actions for some materials in the equipment maintenance function

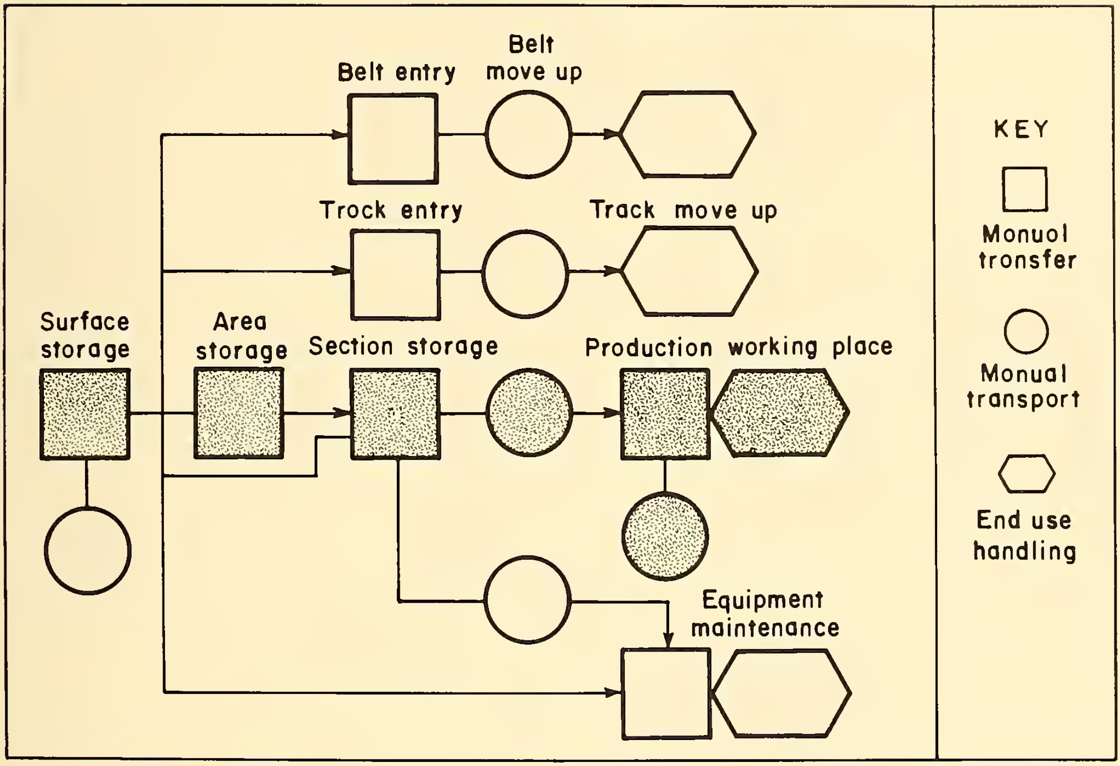
	Accidents	
	Stationary	Walking
Face equipment components.	7	2
Repair supplies (oil cans, wire reels, etc.)........	5	4
Repair supplies (toolboxes, gas bottles.......	5	3
Shuttle car components....	7	0
Other equipment components	7	0
Belt conveyor components..	4	0
Total................	35	9



Major materials ranked by usage frequency

- Roof bolts, plates, and shells
- Wedges
- Rock dust sacks
- Timber - boards and headers
- Header, steel
- Bits - continuous miner
- Bits - roof drill
- Timber - round posts
- Crib block
- Brattice cloth

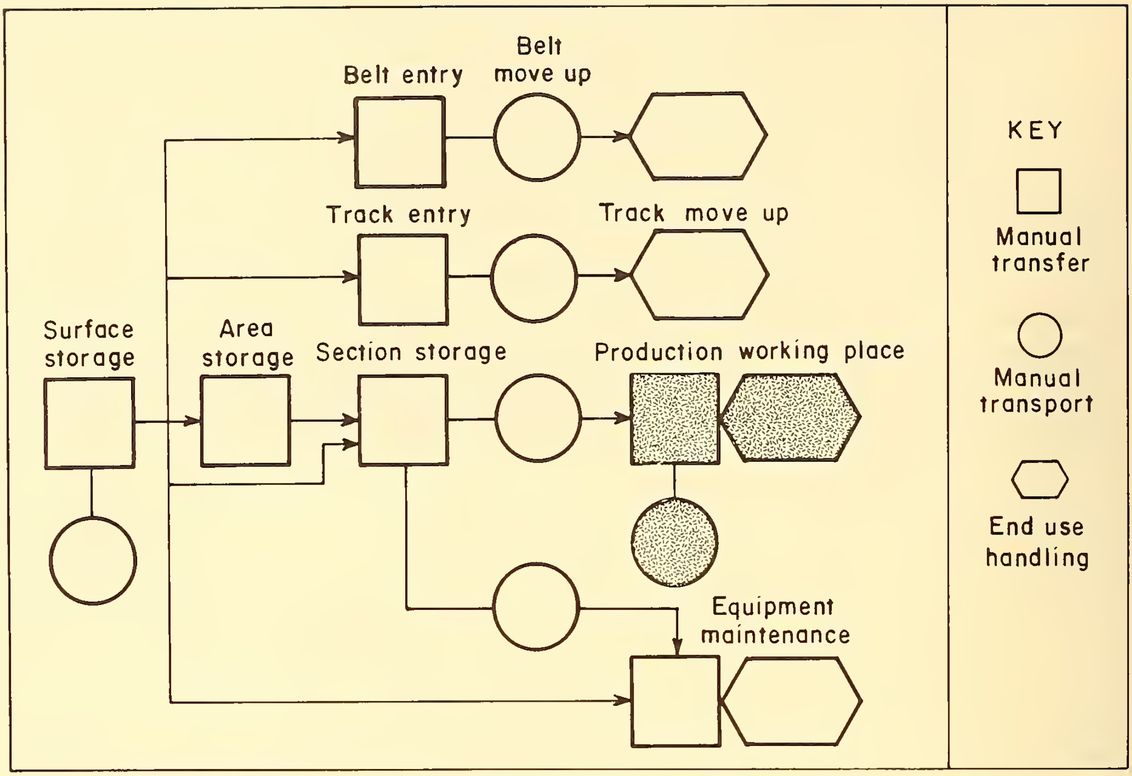
FIGURE A-1. - Production supply function flow path with materials used.



Major materials ranked by usage frequency

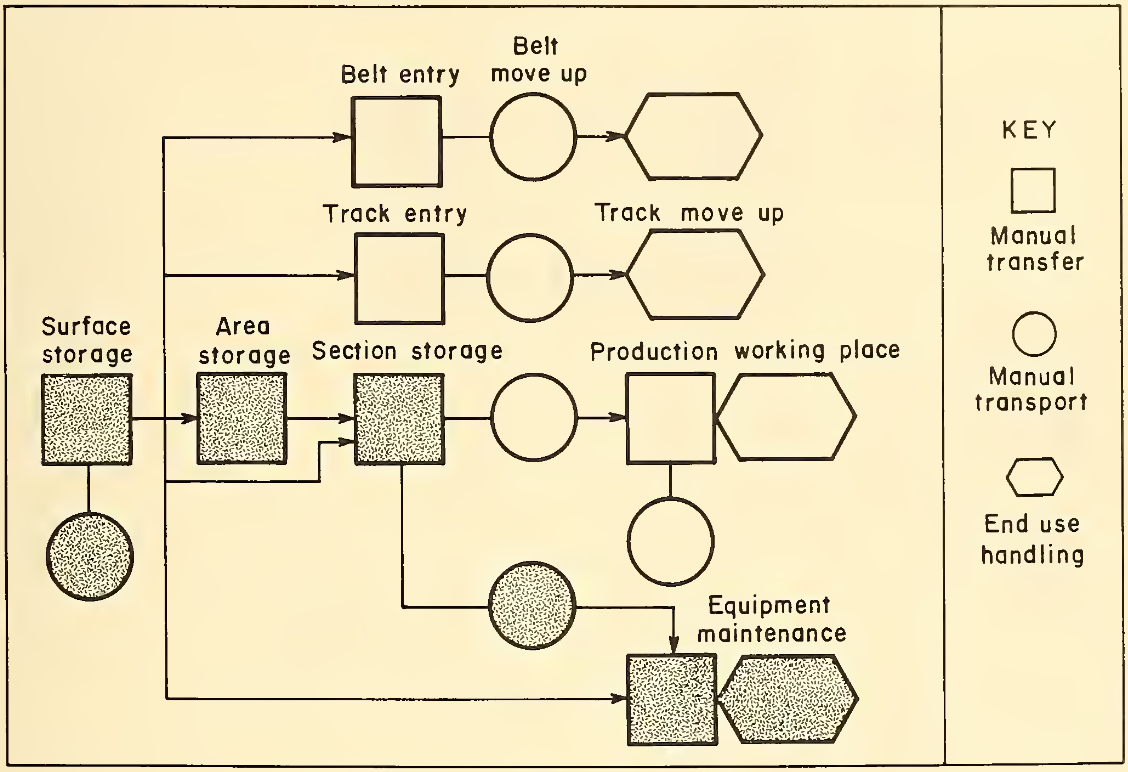
- Wedges
- Rock dust sock
- Timber - boords and heoders
- Stopping blocks
- Timber-round posts
- Crib block
- Mortor mix sock
- Pipe-PVC ond steel

FIGURE A-2. - Mine maintenance function flow path with materials used.



Major materials ranked by usage frequency
- Roof jack, portable
- Trailing cable
- Wire

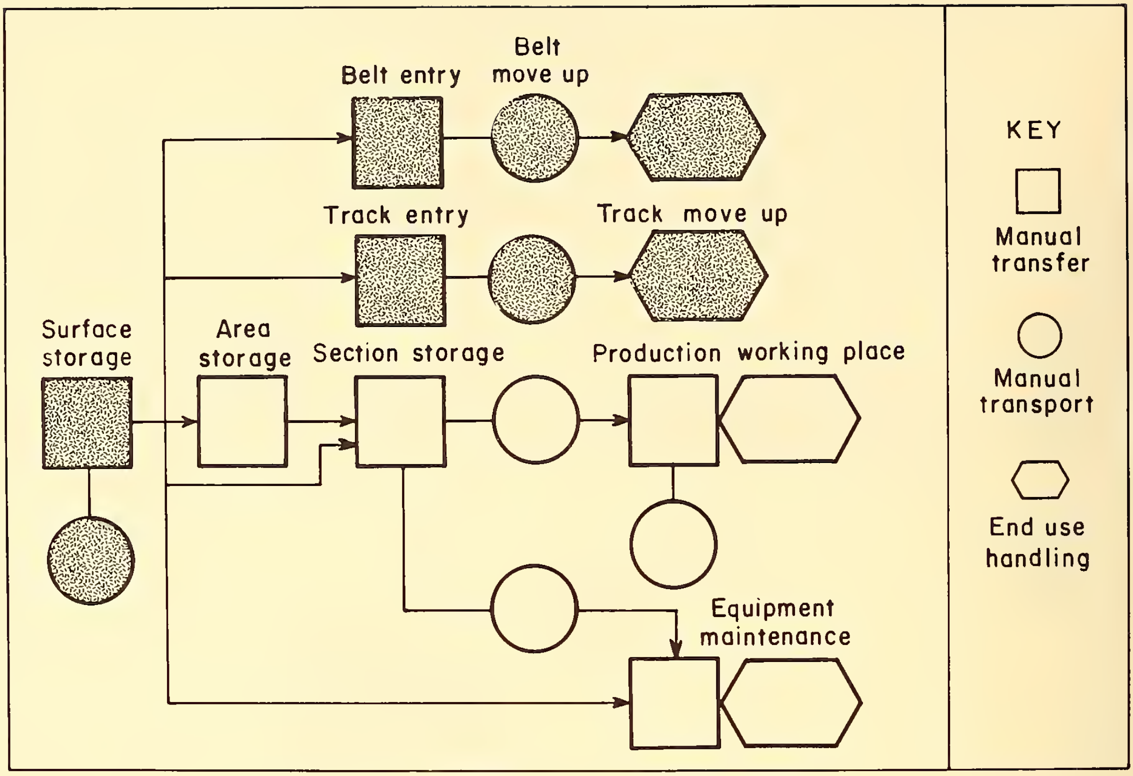
FIGURE A-3. - Production end use function flow path with materials used.



Major materials ranked by usage frequency

- Lubricant containers
- Equipment components
- Bottles, welding gas
- Tool boxes

FIGURE A-4. - Equipment maintenance function flow path with materials used.



Major materials ranked by usage frequency

- Conveyor belt
- Carrying idlers
- Return idler
- Belt support stand
- Haulage rail
- Timber

FIGURE A-5. - Section move function flow path with materials used.

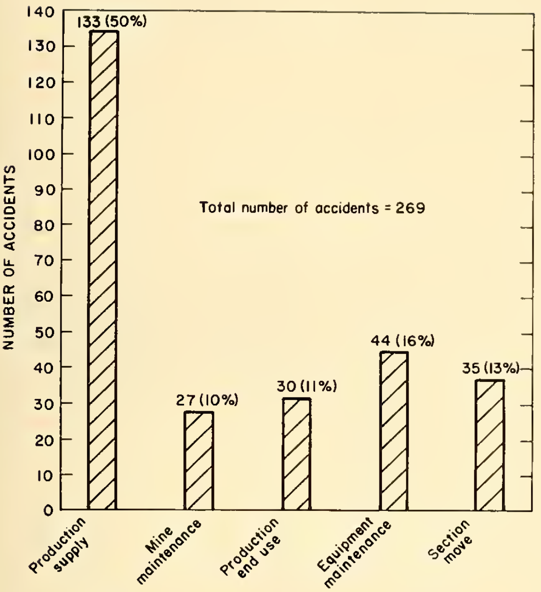


FIGURE B-1. - Accident frequencies far different handling functians.

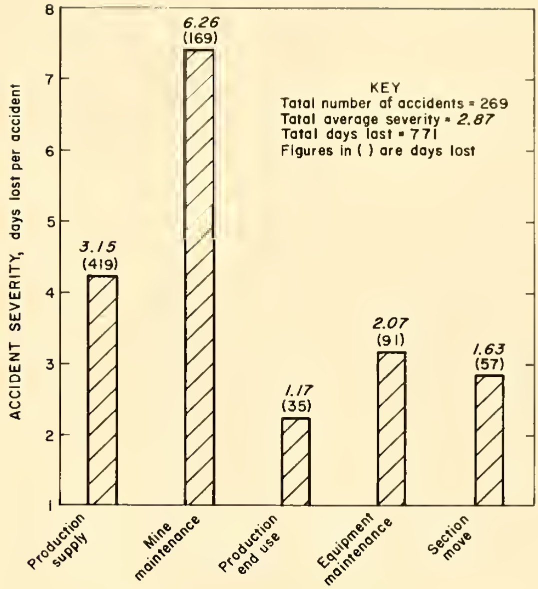


FIGURE B-2. - Accident severity far variaus handling functians.

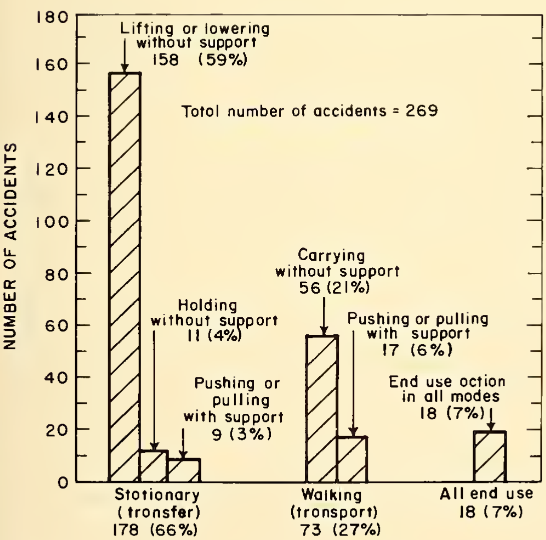


FIGURE B-3. - Accident frequencies far different hazardaus manual actions.

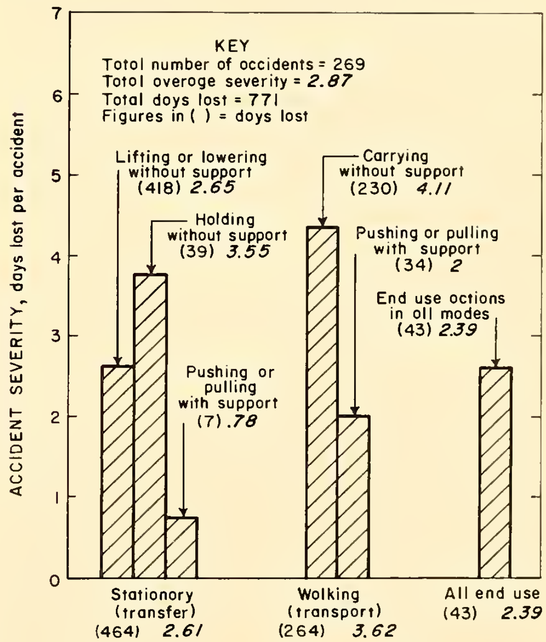


FIGURE B-4. - Accident severity for variaus manual hazardaus actians.

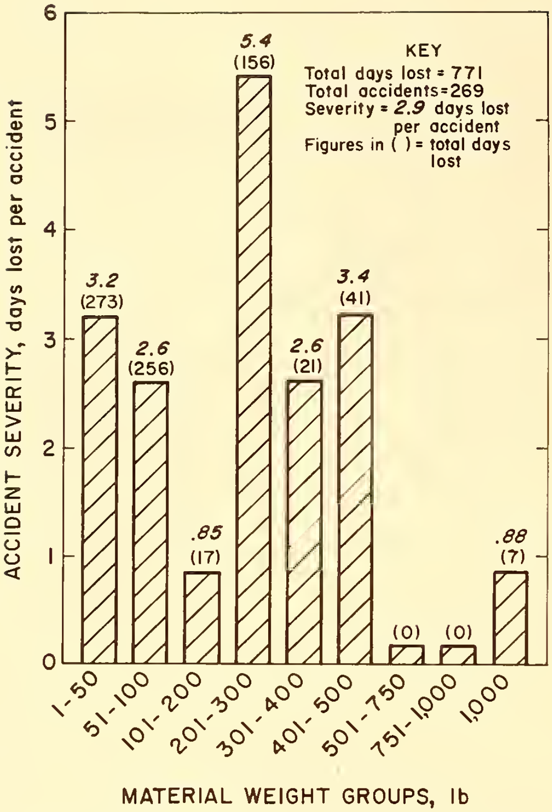


FIGURE B-5. - Accident frequencies for various manual handling accidents in materials weight groups.

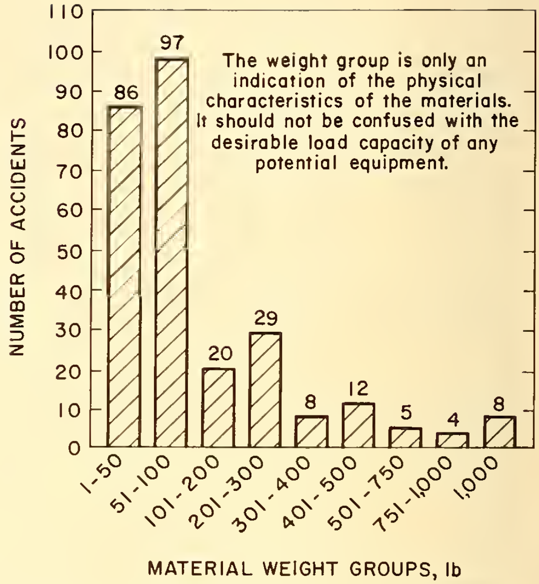


FIGURE B-6. - Accident severity for manual handling accidents in various materials weight groups.

ACTIVITIES AND OBJECTS MOST COMMONLY ASSOCIATED WITH UNDERGROUND COAL MINERS' BACK INJURIES

By Robert H. Peters[1]

ABSTRACT

Recent national statistics on factors associated with underground coal miners' back injuries are presented. Particular attention is given to describing combinations of events and conditions that account for over 1 pct of these back injuries. Most of the statistics presented in this paper are derived from Mine Safety and Health Administration's (MSHA) records of injury data and short narrative accounts of injuries. It is concluded that since there are such a variety of factors that contribute to back injuries, significant improvements can be realized only through a broad, multifaceted approach to prevention.

INTRODUCTION

There is reason to believe that the environmental conditions that exist in many underground coal mines pose relatively unique barriers to the prevention of back injuries. Compared with most other types of industrial settings, many underground coal mines are not as well illuminated, are wetter, and have more restricted work spaces. The problems of illumination and water can result in back injuries caused by slipping on wet or muddy surfaces or tripping over things that could not be seen clearly. Coal seams that prevent miners from standing erect contribute to the occurrence of back injuries because miners who must stand, walk, lift, and carry things in a stooped position place significantly more stress on their backs than those who can perform these activities while standing erect.

Back injuries are unquestionably the most common type of injury suffered by miners. A few statistics based on injury data reported to MSHA help to portray the significance of the problem.

Table 1 presents the total reported injuries and overall incidence rates and severity measures associated with back injuries suffered by U.S. coal miners while working underground for each year from 1978 to 1981. No trends are apparent in the figures for total injuries and incidence rates. The total number of reported back injuries over this 4-yr period range from 2,654 to 3,779, and do not appear to be declining. The overall incidence rates over this 4-yr period range from 2.74 to 3.39, and also do not appear to be declining. The overall severity rates over this 4-yr period range from 102 to 141, and definitely portray a trend of increasing severity.

It should be noted that not all back injuries (especially the "minor" ones) are reported to MSHA. Therefore, it is very likely that, in reality, the numbers and incidence rates associated with back injuries are higher than those portrayed in table 1.

TABLE 1. - Number, incidence rate, and severity of back injuries suffered by coal miners while working underground

Year	Number	Incidence rate[1]	Severity[2]
1978.......	2,654	2.74	102
1979.......	3,617	3.14	114
1980.......	3,779	3.39	136
1981.......	3,007	3.00	141

[1]Incidence rate is the number of back injuries per 200,000 worker-hours.

[2]Severity is the number of lost workdays per 200,000 worker-hours.

[1]Research psychologist, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

Table 2 breaks down the total number of accidents that occurred inside underground coal mines during 1981 according to MSHA's categorization scheme for classification of accidents. MSHA's accident classification scheme attempts to identify the circumstances that contributed most directly to the resulting accident. The first column of numbers in table 2 indicates that handling material accounts for a much greater percentage of total injuries than any other single class. As shown in the last column of table 2, injuries to the back (as opposed to other parts of the body) account for almost half (42.7 pct) of the injuries associated with handling material. Within classes containing relatively large numbers of injuries, the back is generally associated with more injuries than any other part of the body. Altogether, back injuries account for 23 pct of all injuries reported to have occurred inside underground coal mines during 1981.

In terms of the number of workdays missed before the injured miner is able to return to work, back injuries are a relatively severe type of injury. Twenty-six percent of the lost-time back injuries that occurred inside underground coal mines during 1981 resulted in the miner missing more than 4 weeks of work. The average number of workdays missed after miners injured their backs was approximately 7 days longer than the average number for all nonfatal injuries (39 versus 32 days). Altogether, 31 pct of all workdays lost to nonfatal work-related injuries were attributed to injuries of the back.

TABLE 2. - Injuries suffered by underground coal miners during 1981, broken down by accident classification and showing the percent of back injuries in each class

Accident classification	Percentage	Percentage that are back injuries
Electrical (current producing)	1.7	1.6
Entrapment	.1	0
Exploding vessels under pressure	.1	0
Explosives and breaking agents	.2	0
Falling or sliding rock or material	.6	11.5
Fall of face or rib	2.3	12.9
Fall of roof	19.4	3.9
Fire	.2	3.2
Handling material	28.1	42.7
Nonpowered hand tools	7.5	10.8
Nonpowered haulage[1]	.2	31.0
Powered haulage[1]	11.8	16.3
Hoisting[1]	.4	6.3
Explosion of gas or dust	.7	.1
Inundation	.1	0
Machinery (includes power tools and mining machines)[1]	12.1	7.6
Slip or fall of person	9.8	21.4
Stepping or kneeling on object	2.3	10.5
Striking or bumping[2]	1.7	10.5
Other	.7	28.7
Total and percentage	100.0	23.0

[1]Accidents caused by the motion of the object.

[2]Excludes accidents that occurred while handling material, using handtools, or operating and/or riding machinery or haulage.

In total, these injuries represent only a tremendous economic cost to coal companies, to miners and their families, and to society; they represent a tremendous amount of human suffering. It is obvious that there is a great need to find better ways to prevent back injuries to underground coal miners.

The success of those who search for better ways to prevent back injuries to underground coal miners is, in part, dependent upon the accuracy of their understanding of the causes of back injuries. This paper attempts to add to what is currently known about the causes of back injuries to underground coal miners. The general approach employed was to review data from reports on an extensive number of back injuries recently suffered by underground coal miners, to identify the basic types of accidents causing these injuries, and to search for events and conditions that are commonly associated with them. The first section describes how the data were obtained, the types of injuries that were included, and the types of analyses that were performed. The second section presents the results of data analyses and a few speculations concerning how various types of accidents might be prevented. The third section summarizes the findings.

THE SOURCE OF DATA AND METHODS OF ANALYSIS

The types of injuries included in the statistics presented in the remainder of this paper are those in which a coal miner suffered a ruptured disk or a strain or sprain of his or her back while working at an underground location. The data are derived from reports that the operators of U.S. coal mines sent to MSHA concerning injuries their employees suffered while at work during 1981. Employers are required by 30 CFR 50.2 to report to MSHA all injuries that cause an employee to miss one or more days of work. However, if the injury did not require the employee to miss work, and meets certain other conditions (as defined in 30 CFR 50.2), the employer is not required to report it to MSHA. Therefore, it should be noted that the statistics are based on reports of both lost-time and no-lost-time injuries, but that employers are not required to report certain types of no-lost-time injuries.

After the injury report is received by MSHA's Health and Safety Analysis Center, much of the information on it is transformed into code numbers that correspond to predetermined categories. For example, there are a list of codes for describing the types of acitivity miners were performing at the time they were injured. These code numbers are then entered into a computer file. Using a computerized retrieval system, information from this file can be selectively retrieved and various types of statistics can be calculated.

The primary goal of this paper is to use this information to identify the types of activities, objects, and conditions most frequently associated with the 2,492 reported cases of an underground coal miner suffering a back sprain or strain during 1981. The first step toward this goal was to determine which categories for describing the type of accident were used most frequently.

Ninety-seven percent of these injuries are categorized as one of three basic types of accidents: overexertion in attempting to move objects, falls to the ground, and jolts to the occupants of vehicles. In order to get a clearer picture of the circumstances that often lead to each of these three types of accidents, the injuries within each major category were further broken down. Depending upon which is more conducive to understanding the factors that may have contributed to the accident, the second level of breakdowns were based upon either the type of activity the miner was performing or the type of object that caused or contributed to the injury. Next, sets of descriptions of each accident were retrieved for each group of injuries that, on the basis of the second

level breakdown, accounted for more than 1 pct of the total, i.e., more than 24 injuries. These verbal accounts, called narratives, generally consist of one or two sentences describing what the miner was doing at or shortly before the time back pain was noticed.

Included in the previously mentioned injury reports that mine operators file are written descriptions of how the accident occurred. These narratives are also put into a computer file from which they can be selectively sorted into groups and retrieved. As mentioned earlier, sets of narratives were generated for each group of injuries accounting for more than 1 pct of the total.

Each of these groups of narratives was reviewed and a tally was kept of the types of activities, actions, environmental conditions, etc., that appear to have contributed to each miner's back injury. Conclusions based on these tallys are presented as each type of back injury accident is discussed. However, for a variety of reasons, these conclusions should be interpreted cautiously, as rough approximations to understanding what actually happened. In some cases, the injured miner or the individual who wrote the narrative may not have used the most accurate and descriptive language to convey what happened. For example, one narrative states that, "the miner hurt his back while moving cable," which does not indicate whether the miner was lifting, pulling, or hanging a cable. Fortunately, most narratives are more precise in the language they use.

It is recognized that in some cases, especially those involving back pain owing to overexertion, it may be impossible for miners to pinpoint the event that caused their backs to hurt. The miner's back may have begun to hurt gradually over a period of time that he or she was performing a variety of activities, all of which contributed to overexertion of the back muscles. Although the narratives may be somewhat ambiguous and contain some error, they significantly improve one's ability to understand how miners commonly injure their backs.

PRESENTATION OF THE DATA AND ITS IMPLICATIONS

This section presents a detailed discussion of each of the three major categories of accidents. Each major type of accident is further broken down into subsets that possess some type of common element, such as similarities in the type of activity the victim was performing, the type of object with which the victim was working, or the type of bodily movement the miner was attempting at the time of the injury. As indicated in table 3, more back injuries were attributed to overexertion than to any other category for describing the type of accident. Although 79 pct were classified as injuries because of overexertion, significant numbers were also classified as falls (11 pct) and jolts (7 pct).

TABLE 3. - Back injuries suffered by underground coal miners during 1981 by accident type

Accident type	Number of injuries	Percentage
Overexertion......	1,958	79
Falls.............	263	11
Jolts.............	183	7
Other.............	88	3
Total........	2,492	100

OVEREXERTION IN MOVING OBJECTS

Table 4 breaks down back injuries owing to overexertion by the types of objects miners were attempting to move. The most common types of objects being moved at

the time of a back injury were electric cables, broken rock and coal, timbers and posts, metal objects (not elsewhere classified), belt conveyors, wooden objects (not elsewhere classified), steel rails, bagged material systems, jacks, mining machines, roof bolts, oil containers, cement blocks, buckets and cans, metal covers and guards, pry bars, motors, wheels, and boxes. As table 4 indicates, the movement of each of these categories of objects accounts for at least 1 pct of the total and, together, they account for 83 pct of all back injuries due to overexertion.

TABLE 4. - Overexertion back injuries suffered by underground coal miners during 1981, by the type of objects associated with the injury

Type of object	Number of injuries	Percentage
Electric cables.....	233	11.9
Broken rock and coal	231	11.8
Timbers and posts...	198	10.1
Metal objects[1]......	156	8.0
Belt conveyor systems............	99	5.1
Wood objects[2].......	82	4.2
Steel rails.........	82	4.2
Bagged materials....	82	4.2
Jacks...............	61	3.1
Mining machines.....	49	2.5
Roof bolts..........	49	2.5
Oil containers......	48	2.5
Cement blocks.......	47	2.4
Buckets and cans....	46	2.3
Metal covers and guards.............	43	2.1
Pry bars............	33	1.7
Motors..............	33	1.7
Wheels..............	32	1.6
Boxes...............	30	1.5
Other...............	324	16.6
Total..........	1,958	100.0

[1]Does not include metal objects such as rails, roof bolts, jacks, motors, etc., that are listed in other categories.

[2]Does not include timbers, posts, caps, and headers.

Electric Cables. Based upon MSHA's categorization scheme, the movement of electric cables was associated with more back injuries due to overexertion than the movement of any other type of object. Forty-two percent of the narratives for these accidents indicate that the miner was pulling on a cable, 17 pct indicate that the miner was lifting a cable, and 11 pct indicate that the miner was hanging or lowering a cable. The remaining narratives use less specific terms to describe the miner's actions (e.g., moving or handling cable) or describe relatively unique types of accidents.

Broken Rock and Coal. The second most common category of object associated with overexertion injuries was broken rock and coal. The movement of rock and coal accounted for almost as many overexertion injuries as cables (11.9 versus 11.8 pct).

Approximately half of the narratives attribute the injury to shoveling and a quarter of the narratives attribute the injury to the manual lifting of broken rock and coal. The remaining narratives attribute the injury to other types of movement such as the dragging, rolling, or pulling of rocks.

Timbers and Posts. The third most common category of objects associated with overexertion injuries consisted of timbers, posts, caps, and headers. The narratives refer to timbers and posts much more frequently than caps and headers. The types of movements most often mentioned in the narratives are lifting, 37 pct; loading and unloading, 16 pct; and throwing, 10 pct. The remaining narratives generally use less specific terms to describe the miner's actions such as setting, moving, or handling timber. The narratives usually describe back injuries due to throwing as "twist" of the back, suggesting that the injury occurs because miners often twist their body instead of pivoting on their foot when throwing timbers.

Metal Objects (not elsewhere classified). A review of the narratives indicates that there is no one specific type of metal object that accounts for a significant portion of the injuries in this category. The types of items mentioned include pipes, wire, coupling hitches,

ramps, and roof bolt augers. The types of movements most often mentioned in the narratives are lifting, 52 pct; loading and unloading, 10 pct; carrying, 10 pct.

Belt Conveyor Systems. A review of the narratives indicates that the movement of each of three elements of belt conveyor systems was associated with roughly a quarter of the overexertion back injuries in this category. One of these elements is the belt structure. Narratives mentioning belt structures usually state that miners were lifting, unloading, or carrying them when their backs were injured. A second element is rollers. Narratives mentioning rollers usually state that miners were lifting or changing them when their backs were injured. The third element is the belt itself. Narratives mentioning belts usually state that miners were pulling, lifting, or loading belt material.

Wooden Objects (not elsewhere classified). The types of items most often mentioned in the narratives for this category are crib blocks, boards, crossbars, planks, and props. Other than crib blocks, which account for almost half, no one specific type of wooden object is associated with a significant portion of this category of injuries. Most narratives indicate that these injuries occurred as the object was being lifted.

Steel Rails. About half of the narratives for this category of injuries indicate that the injury occurred while lifting rails. Most of the remaining injuries are attributed to loading, pulling, or pushing on rails. These accidents usually occur during the installation of rails as tracks or as roof supports.

Bagged Materials. The narratives reveal that three-quarters of the bags being moved when the injury occurred contained rock dust, and that the others contained tools, cement mix, powder, and sand. Almost all the narratives state that the miner's back was injured while lifting or loading bags. A few narratives give the weight of the bag(s) that had been lifted when the injury occurred. Those which do, indicate that the rock dust bags weighed 50 lb, and that the bags of other materials were heavier, up to 100 lb each.

Jacks. Most narratives for this category state that miners were lifting a jack when their backs were injured. However, several narratives state that the miner was using a jack to remount derailed vehicles when the back injury occurred.

Mining Machines. This category of back injuries includes those suffered during the operation, maintenance, or repair of underground mining machines, but does not include injuries suffered while lifting motors or while riding or operating vehicles. The narratives indicate that approximately half of these injuries were associated with roof bolting machines. Several injuries are also attributed to lifting rock dust machines.

Roof Bolts. About half of the narratives indicate that the back injury was received while the miner was unloading or lifting roof bolts. About one-third state that the miner was injured while attempting to bend a roof bolt.

Oil Containers. Most narratives for this category of back injuries state that the injury occurred as barrels of oil were being lifted or loaded onto equipment. Several injuries occurred while oil was being poured into machinery and while miners were attempting to upright a barrel that was lying on its side.

Cement Blocks. About half of the narratives for this category of back injuries indicate that the injury occurred as cement blocks were being lifted and/or carried. Roughly a quarter of the narratives state that the injury occurred while blocks were being loaded or unloaded.

Buckets and Cans. Most narratives for this category of back injuries indicate that the injury occurred during the movement of buckets or cans of oil, grease, or water. Many narratives state that the bucket or can being moved was the 5-gal size.

Metal Covers and Guards. Most narratives for this category of back injuries reveal that the injury occurred during the removal or installation of the metal guards, covers, and canopies on underground powered equipment. The narratives also suggest that several of the back injuries in this category occurred as battery lids were being lifted.

Pry Bars. Almost all narratives for this category of back injuries indicate that the miner was using a pry bar or crowbar to pry or lift on parts of machines or equipment. A small number attribute the injury to prying down loose top.

Motors. The narratives for this category of back injuries generally state that the injury was received while attempting to lift an underground mining machine's motor.

Wheels. Most narratives for this category of back injuries reveal that the injury occurred when tires were being loaded or unloaded, or when a tire was being lifted onto a vehicle's wheel unit.

Boxes. One and one-half percent of the overexertion back injuries were attributed to the movement of boxes. The types of boxes mentioned most frequently in the narratives are toolboxes, dust boxes, and boxes of cutting bits for the continuous miner or bolter.

IMPLICATIONS FOR PREVENTION

The data suggest that there is an especially great need to (1) improve upon present methods and equipment for manually handling power cables, broken rock and coal, and timbers and posts in underground coal mines, or (2) find ways to lessen the amount of human (as opposed to mechanical) effort that must be devoted to handling these materials. The data also suggest that there is a need to prevent miners from using shovels in ways that are likely to place too much stress on the back. Miners should be discouraged from using shovels to lift objects that are too big, or shoveling for prolonged periods of time without rest. Shoveling can place unusually great stress on the back. Therefore, individuals with a history of back problems should be especially careful not to overexert themselves while shoveling. The data also suggest that miners should be discouraged from trying to throw objects as heavy and cumbersome as timbers.

Potter[2] presents tables of data concerning the recommended maximums for the amount of weight that should be lifted, pushed, or pulled by individuals according to their age and sex. He goes on to list the common weights of many of the objects that must be manually moved in underground coal mines, and points out that many of these objects exceed the recommended limits for most types of individuals. On the basis of these data, Potter suggests that several types of mining supplies and materials should be manufactured and packaged in smaller quantities.

FALLING TO THE GROUND

The second type of accident that accounts for a significant portion of miners' back injuries is falling to the ground. In 1981, 10.6 pct of the back injuries suffered by underground coal miners were the result of falling to the ground. Back injuries due to falls were further broken down by the activity the miner was performing at the time of the fall. The activities mentioned most frequently are walking, 26 pct, and handling supplies, 24 pct. Several miners also injured their backs while getting on or off equipment, handling timber, and moving cable. However, in terms of the portion of total back injuries, the number associated with these last three activities is relatively insignificant. Therefore, only falls associated with walking or handling supplies will be discussed.

[2]Potter, H. H. Back Injuries--Causes and Cures. Pres. at Fall Meeting, Soc. Min. Eng., AIME, Denver, CO, Nov. 18, 1981, 10 pp.; available for consultation at MSHA's Division of Coal Mine Safety and Health, Denver, CO.

Walking. A review of the narratives for back injuries associated with falls while walking reveals that most such accidents were the result of slipping on mud or a wet surface. Other phases frequently used to describe the cause of falls are "stepping in a hole," and "tripping over" things on the ground.

Handling Supplies. A review of narratives for back injuries associated with falls while handling supplies reveals that such accidents were most frequently the result of slipping on a wet or muddy surface while carrying something, or slipping while trying to pull on something.

Possible ways to prevent such accidents include keeping work areas as dry as possible, keeping walking surfaces as level as possible and free of obstacles, improving illumination along walkways, and using boots with tread designs that prevent slipping on wet surfaces.

JOLTS

The third major type of accident resulting in back injuries consists of jolts to the occupants of underground vehicles. In 1981, 7.3 pct of the back injuries suffered by underground coal miners were the result of the miner's body striking against a relatively stationary object. These injuries were further broken down by the activity being performed at the time of the accident. It was found that 28 pct of the victims of this category of accidents were operating a shuttle car, and 21 pct were riding in a mantrip or Jeep.

Operating Shuttle Cars. A review of narratives for back injuries to the operators of shuttle cars reveals that such injuries were almost always due to the operator being jolted when the shuttle car ran over a bump, hole, or rough spot in the mine floor. Some narratives describe these jolts as being so severe that they cause operators to strike their heads on the canopy above them. It would be possible to prevent some of these accidents by doing the following: keeping the floor of the mine more level; cautioning shuttlecar operators to slow down for rough spots; increasing illumination of the mine floor, or providing some type of warning that signifies the presence of rough spots; putting cushions in the seat and on the canopy above the operator; and requiring the use of seatbelts. It should be noted that these suggested solutions are by no means an exhaustive list, and that it may not yet be economically feasible to implement some of them.

Riding in Underground Transportation Vehicles. Back injuries suffered by the occupants of underground transportation vehicles were usually caused by one of two types of mishaps. The first type of mishap is that, like shuttle car operators, miners received back injuries from being jolted when their vehicle ran over uneven places in the mine floor or in the tracks on which certain types of vehicles run. The second type of mishap, which caused as many back injuries as the first, was the collision of vehicles. Such collisions result in sudden jolts to the vehicle's occupants, sometimes causing them to experience back pain. Many of the measures suggested for preventing back injuries to shuttle car operators would also be applicable to the operation of underground transportation vehicles. The following measures might also reduce the number of vehicle-related back injuries: encouraging miners to keep the roadways free of parked vehicles and other obstructions; encouraging vehicle operators to be more attentive to possible obstructions in the roadway; and ensuring that vehicles, their brakes, and the track on which they run are properly maintained. Consideration might also be given to the use of better shock absorbing devices on these vehicles.

SUMMARY AND CONCLUSIONS

A review of recent data on back injuries suffered by underground coal miners suggests that many factors contribute to their occurrence. The action most frequently associated with these injuries is overexertion in lifting things. The types of things being lifted that are most frequently associated with back injuries are cables, broken rock and coal, and timbers and posts. Another common form of overexertion causing back injuries is pulling on things. The object that causes the majority of back injuries due to pulling is power cables. Another activity associated with many back injuries due to overexertion is the shoveling of broken rock and coal.

Although most back injuries are due to overexertion, a significant number of them are due to falls and jolts. The injuries due to falls are typically the result of slipping on a wet or muddy surface, or tripping over something while handling materials or while simply walking. The injuries due to jolts are typically the result of running over uneven places in the mine floor while riding in shuttle cars or underground transportation vehicles. Another common type of mishap causing back injuries to the occupants of underground transportation vehicles is the collision of their vehicle into another vehicle.

The fact that there are so many factors that contribute to underground miners' back injuries suggests that there are a variety of actions that could be taken to reduce back injuries, but that no one approach will be a panacea. The fact that most back injuries are the result of overexertion in the manual movement of things suggests that back injuries could be reduced most significantly by changing the way these things are moved, or eliminating the need to move some of them. Thus, although it is very important that more attention be devoted to the prevention of falls and jolts, there is an extremely great need to devote more attention to the prevention of overexertion injuries.

ANALYSIS OF COAL MINING BACK INJURY STATISTICS

By Terrence J. Stobbe[1] and Ralph W. Plummer[2]

ABSTRACT

Injury and illness in industry are at best complex problems. One of the biggest of these problems is the overexertion injury. This is commonly characterized as a strain or sprain injury. In its most severe form, it occurs to the back and necessitates disk surgery.

This study collected and analyzed existing data of job-related overexertion injury data for coal miners employed by a major coal company during the years 1977-82. The purpose of this analysis was to determine the magnitude of overexertion injuries, to determine the severity of the injuries, and to identify specific activities that account for large numbers of back injuries.

INTRODUCTION

The desire to control injury and illness in coal mining is motivated by humanitarian and economic factors. The need to reduce pain and suffering not only to the injured persons, but to their families and associates as well, is obvious. The economic basis is perhaps less clear. The injured miner often loses a significant portion of his or her income while off the job. The employer pays the medical and indemnity costs of workmen's compensation, along with an equivalent amount in hidden costs, such as retraining, administrative functions, etc. Coal mining is recognized as being one of the most hazardous industries. The high degree of hazard is reflected in the associated workmen's compensation costs. In West Virginia, underground coal mining has a base rate for compensation which is second only to high-rise structural steel work. The base rate, which is almost 20 pct of payroll dollars, is more than twice the third place job activity--working in a sawmill. The base rate is adjusted up or down based on individual company experience and, as a result, some coal companies pay compensation premiums that are equal to three-fourths of payroll dollars.

Reduction of these costs is dependent on understanding their causes. One well-known cause is the overexertion injury. This type of injury ranges from strain and sprain to the more severe back injury that requires surgery. Nationally, these injuries account for 30 to 40 pct of all reported injuries, and at least as high a percentage of the compensation costs. Back injuries are a subset of these injuries, which account for about 20 pct of all reported injuries.

The situation in coal mining is similar but worse. Accident statistics for West Virginia show that in 1979 back injuries accounted for 23 pct of all injuries. MSHA[3] reported that, in 1980, back injuries accounted for 26 pct of all coal mining injuries. The associated compensation costs are estimated to be 30 to 40 pct of the total compensation costs (for the company in this study). Having identified the source of a significant portion of the compensation costs, we must look to understanding the cause of overexertion and back injuries.

In trying to understand the causes of these injuries, it is instrumental to

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[3]Potter, H. H. Lack of Mechanization in Some Coal Mine Tasks. Mine Safety and Health Magazine, Dec.-Jan. 1982, pp. 8-13.

look first to general industry where most of the back injury related research has been. This research has shown that the major causes of back injury are materials handling, slip-trip, and push-pull. Within these categories, materials handling predominates, and it is considered to be such a major problem that NIOSH has published a lengthy Work Practices Guide for Manual Lifting[4] that summarizes what is currently known about the problem as well as providing control recommendations. In essence, the guide reports that people who lift too much too often experience back and overexertion injuries. The guide then proposes a method for estimating relatively safe weights to lift under ideal lifting conditions.

Looking now at coal mining, it is again found that the situation is similar but worse. Materials handling is a major activity in the mines, and in most mines it is increasing in frequency as the rate of mining coal increases.[5] Loads handled are equal to or heavier than those handled in general industry. Typical "man-handled" loads are shown in table 1. The work practice guide emphasizes that its recommendations apply to ideal lifting conditions. However, lifting conditions in coal mining are far from ideal. Loads are bulky and do not have handles, and furthermore, floor conditions vary from dry and uneven to wet, muddy, and slippery.

TABLE 1. - Weights of materials commonly handled in coal mines

Materials	lb
Roof bolts:	
5/8 in by 6 ft, bundle of 10......	55
5/8 in by 10 ft, bundle of 10.....	90
Crossbar, oak, 4 by 6 in by 16 ft...	129
Round post, oak, 6-in diam by 6 ft..	57
Concrete block, 8 by 8 by 16........	62
Cement, 1 bag.......................	80
Rock dust, 1 bag....................	50
Rail, 30 lb, 30-ft length...........	300

[4]U.S. Department of Health and Human Services. Work Practices Guide for Manual Lifting. NIOSH Pub. 81-122, 1981, 183 pp.; NTIS PB 82-178-948.

[5]Work cited in footnote 3.

With respect to the above, the Bureau of Mines sponsored this study of coal mining back injuries. To the extent possible, this description includes such factors as job, task, materials handled, mine height, time of year, repeated injuries to the same miner, and exposure hours.

The results of this study are aimed at reducing back injuries in coal mining. This will be accomplished by applying the result of this study to (1) identifying specific jobs with high back injury frequency rates based on hours of exposure (work); (2) conducting job safety and physical stress anslyses of these jobs to isolate specific tasks or work procedures that increase the risk of back injury; (3) isolating tools, supplies, equipment, etc., that act as causes or agents in a significant number of back injury scenarios; and (4) redesigning or modifying the tasks, work procedures, tools, supplies, or equipment that significantly increase back injuries.

METHODOLOGY

The purpose of this research was to develop a set of statistics that would describe the back injury problem in coal mining in sufficient detail so that future research directions could be identified. Two sources of data were available: the MSHA's Health and Safety Analysis Center (HSAC) data base and individual company accident-injury records. Each data base had advantages to its use. HSAC records covered all of the mining industry, thus a larger data base was available. They were, however, based on a single reporting form, and their accuracy suffered to the extent that different companies and mines use different titles to describe the same job or activity or the same title to describe different jobs and activities. Individual company records were limited in that a much smaller data base was available, but they were superior because considerable background information was available beyond the HSAC reporting form. In addition, a comprehensive review of a large coal producer's back injury statistics was not available in the literature.

In view of the above, individual company statistics were used. Contact was made with a large coal producer and after some discussion it was agreed that the analysis would be mutually beneficial. Access was provided to all of the company's accident records. This included the company's internal first injury report, the HSAC form, the company's internal statistical report, and miscellaneous data that found their way into individual accident files. All of these data were reviewed for the 6-yr period 1977-82, during which a total of 974 back injuries were reported. Correct interpretation of the data required frequent contact with company personnel in a number of areas including the medical department, safety department (corporate and field), mine supervision, industrial relations, compensation, and industrial engineering.

The review of the accident data provided an excellent description of the nature, source, and frequency of back injuries, but without exposure data, it was difficult to interpret. Exposure data were collected with the additional help of the company's industrial engineering group. As expected, collection and interpretation of both exposure and accident data were difficult since there were numerous mine-to-mine inconsistencies in the titles placed on jobs and activities. These inconsistencies were identifiable only with the help of company personnel.

The actual data collection process involved reading all of the information contained in each accident file and coding it for later analyzing using a statistical analysis system (SAS). The following is a partial list of the data collected.

Bureau of Mines identification.

Primary cause.

Secondary cause.

Agent of injury.

Sex of injured miner.

Total mining experience.

Permanent job classification.

Date injury occurred.

Time of day injury occurred.

Date injury reported.

Job being performed when injury occurred.

Total experience in job being performed when injured.

Part of body injured.

The unique feature of this data set is the inclusion of the primary and secondary causes of the injury, as well as the agent of injury. Partial lists of these variables are provided in the following tabulations.

<u>Primary cause</u>:

Lifting-twisting	Jumping from vehicle.
Tripped	Carrying
Slipped	Pushing
Pulling	Hit canopy
Fell	Prying
Shoveling	Hit bump (vehicle)
Stumbled	Twisting
Hit rough road (vehicle)	Pulling down Hit by object
Bend over and/or lifting.	Handling supplies Striking head

<u>Secondary cause</u>:

Crib block	Supply car
Swinging pick	Walking
Landed on seat	Unbalanced load

Secondary cause--Continued:

Lifted over head	Slipped
Timber	Roof bolter
Absence of guard	Fell against post
Wet area	Blasting
Operating motor	Climbing ladder
Twisted body	Slipped on a rock
Climbing railroad car.	Fan house

Agent category:

Steel rope	Bag of rock dust
Plank	Trolley wire
Stone falls	Railroad ties
Concrete blocks	Chunk of coal
Hit canopy	Culvert pipe
Pry bar	Straighten up
Shoveling	Drill unit
Hit roof bolt	Post
Air jack	Stepped in hole
Jarred	Using a wrench

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Primary cause--Continued:

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Crib block	Supply car
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Use of this multiple coding scheme allowed the subsequent analysis to go beyond the usual analysis which reveals that X people were injured lifting, Y pulling, etc.; G people were handling timbers, H bags, etc. Instead it was possible to identify the number injured by lifting by each agent category. Furthermore, this approach permitted the identification of those situations in which the person was lifting a timber and slipped. Clearly, it is not known whether it was the lift or the slip that caused the injury, but the fact that they were lifting a heavy object when they slipped certainly contributed to the injury. The slip would probably not have occurred without the force dynamics that lifting places on the body, and the injury may not have occurred without the sudden body movement owing to the slip. In most conventional data analyses, this would be coded simply as a lift or a slip and the joint cause would be lost.

In addition to developing the descriptive statistics, the effects of mine height, the contribution of back injury repeaters to the overall problem, and the often repeated argument that people take advantage of the back injury to get a few days off during hunting season were studied. Mine height was provided by industrial engineering and grouped into four categories. Where meaningful, the data were statistically analyzed to determine which conditions were significant.

There is one element not included in this discussion--cost data. At the time of writing, this information was still being prepared by the compensation department. When received and analyzed this will make a valuable addition to this study.

RESULTS

The comprehensive review of 6 yr of back injury data results in a massive amount of data. It is not practical to describe all of it in a single paper. Rather, this paper will present the results of selected analyses. The reporting order will be to report the mixed-job statistics first, followed by in-depth analyses of selected jobs. The prevalence of back injuries in coal mining was discussed in the introduction. From a control standpoint, the more interesting question is who suffers these injuries. When the question is discussed with mining management, it becomes clear that a mystique has developed about back injuries within which the persons concerned have developed their own theories of causation, often without supporting data. Common examples which were suggested frequently included

1. They lift the wrong way.

2. They try to lift too much.

3. There is always a rash of them when the miners want a few days off.

4. It is the same miners who get hurt over and over again.

The data analyzed herein do not address the first two issues, so all that can be done is to point out that there is no single best way to lift. The "lifting method is dependent on the nature of the load and environmental circumstances surrounding the lift."[6] With respect to the size of the lift, it is true that miners often lift too much--but who is responsible? Who designs the jobs, specifies the weights of supplies, and determines the work pace? Furthermore, how is an individual miner supposed to know how much he or she can lift?

There were data available in this study to address issues 3 and 4. The use of a back injury to selectively obtain extra time off is supposedly one with some frequency. In the mystique, hunting season is the prime time for convenient back injuries. To evaluate the issue, contact was made with the Natural Resources Departments of the States in which injuries were reported to identify the dates of hunting season during the years studied. The mean number of back injuries that occurred during hunting season was computed and compared year by year to the

[6]Work cited in footnote 4.

mean number of back injuries occurring on any other day of the year. The week preceding hunting season was included with the hunting data. The results, presented in table 2, show that the conventional mystique is wrong. The statistical analysis demonstrates that there are fewer back injuries per day just before and during hunting season, than during the rest of the year.

TABLE 2. - Comparison of back injury rate (BIR) preceding and during hunting season with the BIR during the rest of the year

	Mean	Variance
BIR--hunting............	0.312	0.223
BIR--nonhunting.........	.418	.488

NOTE.--T-test calculated = 2.262. T-test tabular value = 1.645 for a = 0.05.

Issue 4, back injury repeaters, also proved to be more mystique than fact. Table 3 presents the number of injuries per miner during the 6-yr period. Repeated back injuries, at least during the time period studied, were infrequent. The data were examined further to see if there was a pattern to the timing of injuries in the repeater, and none was found. The distribution of job titles among the repeaters was consistent with that of the overall study.

TABLE 3. - Frequency of back injuries per miner during the 6-yr period 1977-82

Number of miners	Injuries
10,000.........................	0
882............................	1
40.............................	2
4..............................	3

The next section of the report addresses the questions of which jobs have a high frequency of back injuries and what causes them (doing what). Table 4 presents the injury frequency and frequency rate for mining jobs with high back injury frequencies. The frequency provides a relative comparison of the magnitude of the problem per job, while the frequency rate indicates the likelihood of getting hurt on a given job by adjusting the frequency for exposure hours. As expected, those jobs requiring considerable manual materials handling are the jobs with the highest rates. The possible exception to this is the shuttle car operator.

TABLE 4. - Comparison of frequency and frequency rates for coal mining jobs

Job title	Frequency, number of injuries	Frequency rate per thousand h
Laborer...........	158	37.05
Trackman-helper...	41	29.42
Brattice worker...	18	18.30
Shuttle car operator.........	95	15.74
Mechanic-helper...	129	13.22
Continuous miner operator-helper..	54	10.73
Roof bolter-helper	67	10.29

In addition to looking at jobs, this study reviewed causes (activities at the time of injury), and agents (things handled or producing the injury). Table 5 presents an overview of the cause of injury. Clearly, materials handling-related injuries dominate the list. The materials handling category includes lifting of all forms (carrying, twisting, bending, single- and two-person lift, etc.). Table 6 presents an overview of the agent handled at the time of injury. In this case, no one category stands out. Handling supplies such as bagged or drummed materials and concrete blocks is the most frequent, but back injuries due to riding in vehicles, handling timbers, planks and posts, and cable handling are close behind. The data presented in table 6 are consistent with the high frequency of materials handling-related injuries found in table 5.

TABLE 5. - High-frequency causes of back injury in coal mining

Causes	Frequency
Lifting[1]	158
Lift-twist[1]	107
Slip-trip	107
Push-pull	93
Bend lift[1]	41
Hit by object	41
Working	24
Unload[1]	19
Operating machine	18

[1]Several causes were combined to form materials handling.

TABLE 6. - High-frequency agents of back injury in coal mining

Agents	Frequency
Handling general supplies	101
Planks, timbers	91
Riding in vehicle	90
Cables	84
Railroad related	69
Tools	57
Shovel, wheelbarrow	52

The data in tables 5 and 6 can be broken down further by investigating the relationship between cause and agent. Table 7 provides a frequency distribution for agents associated with materials handling. Table 8 provides agents for slip-trip, and table 9 for push-pull. Each cause of injury has its own dominant agents.

TABLE 7. - Frequency distribution for agents of materials handling[1] injuries

Agent	Frequency
Planks and timbers	70
Tools and equipment (timber jacks, 21)	69
Supplies	48
Railroad ties-bars	42
Shovel-rocks	41
Cables	38
Bagged materials	28
Drums-cans	18
Wheelbarrow	11
Belts-belt drive	11

[1]Primary cause of 428 back injuries.

TABLE 8. - Frequency distribution for agents of slip-trip[1] injuries

Agent	Frequency
Floor conditions	69
Tools and equipment	13
Railroad related	12
Supplies	7
Stairs	5
Planks and timbers	4

[1]Primary cause of 138 back injuries.

TABLE 9. - Frequency distribution for agents of push-pull[1] injuries

Agent	Frequency
Cable	35
Building supplies	12
Tools and equipment	12
Wheelbarrow	10
Hose	6
Steelrope	4

[1]Primary cause of 93 back injuries.

The preceding discussion has analyzed the overall back injury data for a major coal company. The balance of this section will provide examples of the analysis of job-related injury data by analyzing two of the jobs in detail. In essence, this means breaking down the cause and agent data for two jobs: laborer and shuttle car operator. Of the mining jobs, the laborer job had both the highest frequency and frequency rate. Table 10 shows the frequency distribution of causes of back injury for laborers. The laborer's job consists of setting posts and timbers, laying and retrieving rails, unloading supplies, shoveling, general cleaning activities, etc.

TABLE 10. - Causes of laborer back injuries

(Total cases, 158; frequency rate, 37.05)

Cause	Frequency	pct
Slip-trip	29	18
Riding in vehicle	19	12
Materials handling	76	48
Push-pull	13	8

As would be expected, more than half of the injuries are the result of materials handling or push-pull activities. Another 18 pct are due to slips-trips, but when these are analyzed further, a third of them involve materials handling. The remaining injuries are split between shoveling and riding in vehicles. Shoveling is to some extent a variation of materials handling, but having 12 pct of laborer's back injuries associated with riding in vehicles raises some serious questions about mine vehicle design. A more detailed breakdown of laborer injuries is provided in table 11 by materials handling, slip-trip, and riding in vehicle.

TABLE 11. - Analysis of activity at time of laborer injury

Activity	Frequency	pct
MATERIALS HANDLING		
Timber, plank, railroad ties	18	24
Shovel	12	16
Rair bars	11	14
Supplies, bagged materials, concrete blocks	11	14
Cable	4	5
Other	20	26
SLIP-TRIP		
Floor conditions	14	48
Materials handling	10	34
Using tools	3	11
Others	2	7
RIDING IN VEHICLE		
Floor conditions	6	32
Collision	6	32
Hit object	5	26
Derail	2	10

A similar analysis is provided for the shuttle car operator (tables 12-13). This job was selected because of its contrast to the laborer. In theory, this job involves considerably less materials handling and, in fact, industrial engineering estimated that only 15 to 20 pct of the job is materials handling (compared with 40 to 45 pct for laborer). In spite of this, when push-pull is added to strict materials handling, 53 pct of the back injuries are accounted for. Riding in vehicles accounts for 29 pct, with slip/trip and shoveling accounting for the balance of the injuries. Again, almost one-third of the slip-trip injuries involved materials handling. The high percentage of vehicle-related injuries is perhaps not surprising for a vehicle operator, but it again suggests problems within vehicle design, particularly as it relates to occupant safety. When compared with the estimated job exposure, the high frequency of materials handling injuries raises a question about the relation among the shuttle car operator's seat design, the constant forward flexed posture and vibration exposure, and a predisposition to lifting injuries.

TABLE 12. - Causes of shuttle car operator back injuries

(Total cases, 95; frequency rate, 15.74)

Cause	Frequency	pct
Slip-trip	10	11
Riding in vehicle	28	29
Materials handling	44	46
Push-pull	8	9
Shoveling	5	5

TABLE 13. - Analysis of shuttle car operator activity at time of injury

Activity	Frequency	pct
MATERIALS HANDLING (INCLUDES PUSH-PULL AND SHOVELING)		
Timbers	10	18
Cables	10	18
Bagged materials	7	12
Supplies	6	11
Shoveling	5	9
Wheelbarrow	5	9
Timber jacks	2	4
Other	12	21
RIDING IN VEHICLE		
Floor condition	20	71
Collision	5	18
Other	3	11
SLIP-TRIP		
Floor condition	5	50
Materials handling	3	30
Other	2	20

A final issue of interest is the effect of mine height. Table 14 presents a comparison of the frequency rates associated with the four mine height categories used in this study. The higher ranges were

selected based upon ease of categorization from the company's records. The data should be interpreted with caution since four or less mines are represented in each of the first three categories. The data in the first three categories were pooled to determine whether there appeared to be differences between mines in which miners work standing (>78 in) and those which preclude standing (table 15). The rates suggest that standing is more hazardous, but with only three data points to compare, the differences were nonsignificant.

TABLE 14. - Comparison of back injury frequency rates by mine seam height for one company

Mine seam height, in	Frequency rate
<48	7.51
48 to 60	10.87
60 to 78	4.90
>78	16.61

TABLE 15. - Comparison of back injury frequency rates in mines greater than and less than 78 in for one company

Year	Mine height, in	
	<78	>78
1980	6.5	20.2
1981	3.4	13.7
1982	6.2	8.3
Average	5.4	14.2

CONCLUSIONS AND RECOMMENDATIONS

This paper has provided an overview of a rather massive data collection effort designed to probe the circumstances surrounding back injuries in coal mining. A short paper could not do more than summarize the subject and introduce one method for analyzing the problem. It began by evaluating some of the conventional wisdom and opinions about back injuries in coal mining, and established that for this company, the wisdom was in conflict with the facts. The problems that lead to back injuries are complex, and hese results clearly suggest that the first steps in solving the problem will have to be thorough, quantitative analyses of the situation and not, as has often been done, a reliance on conventional wisdom and opinion. We cannot ever do away with back injuries, but by systematically analyzing the problem, and controlling what is done, how it is done, and who does it, it should be possible to achieve a significant reduction in the back injury rate.

The overall pattern of back injuries was analyzed, and it pointed to a number of conditions as being the source of the problem. The primary source was, as expected, materials handling. This is consistent with similar analyses performed in general industry. Additional indepth analyses conducted on specific jobs also identified materials handling as a major problem, but these also highlighted vehicle-related injuries, often the result of hitting bumps in the haulageway, as being a significant cause. Identification of materials handling as a problem is not a new insight. MSHA's Hershel Potter stated it was a problem years ago. What is new in this research is the potential for a job-by-job breakdown of the pattern of back injuries to determine what approach may work on each job. The other new feature of this effort will be that of tying together the costs and injuries so that both frequent and costly injuries can be examined. The next step in this process will be application of these data to the jobs studied to find practical ways of modifying either job or agent to reduce the risk of injury.

Identifying vehicle riding as a major source of back injury suggests a number of promising research directions. At this point, the cause appears to be a combination of forward flexed posture, continual vibration exposure, and occasional severe jarring which combined to create the injuries. In addition, it appears they form a predisposition to lifting injuries. Much of this relates directly to vehicle design and, as such, is a problem that management can control.

The analyses reported here will be expanded for use in working with company engineers, supervisors, and miners to decrease the injury frequency rate. Future reports will provide a description of one or more innovations that have resulted in the decrease of back injuries among coal miners.

TWO BACK RISKS IN MINING: LIFTING AND PUSHING AND PULLING

By Robert O. Andres[1]

INTRODUCTION

Mining has long had the onus of being one of the most hazardous occupations for the workers involved. The nature of the work is quite physical, and many of the accidents are unpredictable owing to falling roofs or materials. There were about 40,000 disabling injuries in 1974 for the mining and quarrying industries (11),[2] and out of 41 industries reporting to the National Safety Council, underground coal mining had the highest frequency rate and severity rate (35.44 disabling injuries and 5,154 days lost per 1,000,000 employee-hours, respectively). However, not all of these injuries are due to falls of mine roofs; slips and falls on the same level and materials handling showed up as causes of injury also in mining (14). Broken down on the basis of part of the body injured, from 33 to 42 pct of the injuries reported (from underground to open-pit mining) were to the trunk. Between 33 and 44 pct of the total injuries were strains and sprains due to overexertion. These findings for the mining industry echo the statistics for the workplace in general, where 27 pct of all injuries occurred to the trunk, resulting in 38 pct of the total workmen's compensation in 1974 (11).

Recent research has been concentrating on the risks of back injury during manual materials handling, and also during dynamic pushing-pulling. Some of this research and its methodologies will be described briefly, and example applications to the mining industry will be presented.

BIOMECHANICS OF THE LOW BACK

Epidemiological studies have shown that the low back is a structural weak link in the musculoskeletal system. Approximately 80 pct of back injuries occur in the L_4-L_5 or L_5-S_1 region of the spine (1). A large body of evidence indicates that many of these back injuries result from excessive compressive forces on the L_5-S_1 disk (2, 9-10). Cadaver studies have shown that compressive forces in excess of 1,500 lb result in L_5-S_1 disk vertebrae failures in cadavers of males 40 yr old or younger (6, 13). This load level decreases with age, and females have an even lower tolerance. Low-back pain incidents have been shown to increase with predicted compressive forces on the L_5-S_1 disk (5), so the biomechanics of the low-back region will be examined in more detail.

Figure 1 is a free body diagram of the torso showing the different forces that contribute to the compressive force on the L_5-S_1 disk. Only the abdominal force exerted on the diaphragm counteracts the forces due to the upper body mass, the load in the hands, and the forces of the trunk extensor muscles (erector spinae). Static analysis of this situation solves for the L_5SO_1 compressive force; this static model has been applied to load handling by several researchers (3-4, 7). Given the body posture, the weight of the load in the hands, and the position of the hands, these models can predict the compressive force on the L_5-S_1 disk.

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[2]Underlined numbers in parentheses refer to items in the list of references at the end of this paper.

NIOSH WORK PRACTICES GUIDE

One culmination of the biomechanical approach to studying low-back injuries was the development of the "Work Practices Guide for Manual Lifting" by NIOSH (13) in 1981. This document combines epidemiological, biomechanical, physiological, and psychophysical research results to make recommendations about lifting. This amalgamated approach does not pretend to be the final word on lifting techniques; in fact, the major recommendation is that much more research in all of these areas is necessary, but there are several interesting analyses that can and should be applied to jobs as stressful as those found in the mining industry.

Two different lifting limits have been defined in the guide: The maximal permissible limit (MPL) above which load the lift is so hazardous that only a few people could perform it safely, and the action limit (AL) above which weaker individuals are at risk, but most people can safely perform the lift. When exceeded, the MPL dictates that job redesign must be performed, whereas exceeding the AL requires aggressive selection and training procedures to protect those at risk. Figure 2 shows the maximum weight that can be lifted (in a symmetric, sagittal plane, two-handed lift) infrequently (once every 5 min) from floor-to-knuckle height as a function of the horizontal location of the load. The criteria that defined the MPL include (1) epidemiology, musculoskeletal injury and severity rates increase in populations performing work above this level; (2) biomechanics, conditions above the MPL result in L_5-S_1 compressive forces above 1,400 lb, which is not tolerable to most workers; (3) physiology, metabolic rates would exceed 5.0 kcal/min for most individuals above the MPL; and (4) psychophysics, only 25 pct of male and less than 1 pct of female workers have the muscle strength to work above the MPL. These same criteria, applied for the AL, show (1) only a moderate increase in injury and severity rates, (2) a 770-lb compressive force on the L_5-S_1 disk, which can be tolerated by most young, healthy workers, (3) metabolic rates exceeding 3.5 kcal/min for most people working above the AL, and (4) 99 pct of men and over 75 pct of women could lift loads described by the AL.

The following algebraic formula was derived to calculate the AL:

$$\mathrm{Al(lb)} = 90(6/H)(1-0.01|V-30|)(0.7+3/D(1-F/F_{MAX})$$

where H = horizontal location forward of midpoint between ankles at lift origin, or inches,

V = vertical location at lift origin, inches,

D = vertical travel distance between lift origin and destination, inches,

F = average lift frequency, lifts per minutes,

F_{MAX} = maximum frequency which can be sustained (table 1),

then MPL = 3 (AL).

See reference 13 for the limits of these variables. With this brief introduction to the guide, an example application to a mining situation will be presented.

EXAMPLE APPLICATION

Figure 3 schematically represents a situation where a miner lifts rock or coal from the mine floor to a waiting cart. Assuming this takes place frequently throughout an 8-hr shift, $F_{MAX}=12$ (table 1). If the lift is performed once per minute (F=1), the results for just the vertical portion of the lift are

$$AL(lb) = 40(6/18)(1-0.004|7.6-75|)(0.7+7.5/20)(1-1/12)$$

$$= 40(0.333)(1.26)(1.075)(0.917) = 16.54 \text{ lb}$$

$$MPL = 50 \text{ lb}$$

TABLE 1. - Maximum sustained lifting frequency

Period, h	Average vertical location, in	
	>30, standing	<30, stooped
1.........	18	15
8.........	15	12

Therefore, any load material smaller than 16 lb should not overly stress any worker, whereas loads between 16 to 50 lb should only be handled by stronger workers with care, and loads above 50 lb should not be lifted. The control measure in this situation would be breaking the rock up into pieces smaller than 16 lb. If this lift were performed up to five times a minute, the AL would be 10 lb while the MPL would be 30 lb. Although few actual tasks are as simple to analyze as this one, this type of analysis is obviously quite easy to perform as a first attempt to control job stresses.

CART PUSHING AND PULLING

In some mining operations the mined material is loaded on carts, sometimes on rails, which are then manully manuevered. This situation can lead not only to musculoskeletal strains or sprains, but also to slips or falls owing to inadequate coefficient of friction parameters at the shoe-floor interface. A biodynamic model has been developed (8) that predicts the risk of low back injury and the risk of foot slip. This model is not restricted to static push-pull tasks, but only operates in the sagittal plane. The inputs to the computer model are subject anthropometry, body joint motion data, cart handle height, and the forces exerted by the hands on the cart handles.

Figure 4 is an illustration of the laboratory equipment used to gather the model inputs. The model then calculates the reactive forces and moments at each joint, the L_5-S_1 compressive load, and the required coefficient of friction to prevent foot slip. Although this model is still being refined and validated in the laboratory, it will be applied extensively in the field. Example predictions from the model are shown in figures 5 and 6. Figure 5 illustrates the predicted L_5-S_1 compressive forces for an example push-pull situation, while figure 6 is an example of predicted coefficient of friction requirements at the shoe-floor interface during a push.

Field data taken with portable force measuring handles and high-speed movies will be run through the biodynamic model to obtain output similar to figures 5 and 6. From this analysis the following recommendations can be made: (1) The maximum allowable hand forces, which relate to cart loading and resistance; (2) the required coefficient of friction, which relates to the shoe and floor materials, shoe tread design, floor surface preparation, and floor maintenance; (3) cart handle placement to minimize back injury risk (this changes for pushing versus pulling); and (4) the required strength of the worker performing the task. Although this model is still being refined, it represents another tool that should be used to analyze the stresses of physical work.

SUMMARY AND CONCLUSIONS

There are several recently developed analytical tools available for studying working situations, such as mining, that have high musculoskeletal injury rates and severity rates. Only two techniques of predicting overexertion injuries to the low back have been discussed in this paper, along with some example applications to mining. As research progresses in ergonomics, more use must be made of its results by the industries that can benefit most from its applications; hence, a unique possibility for cooperation among academia, management, and labor exists and should be pursued.

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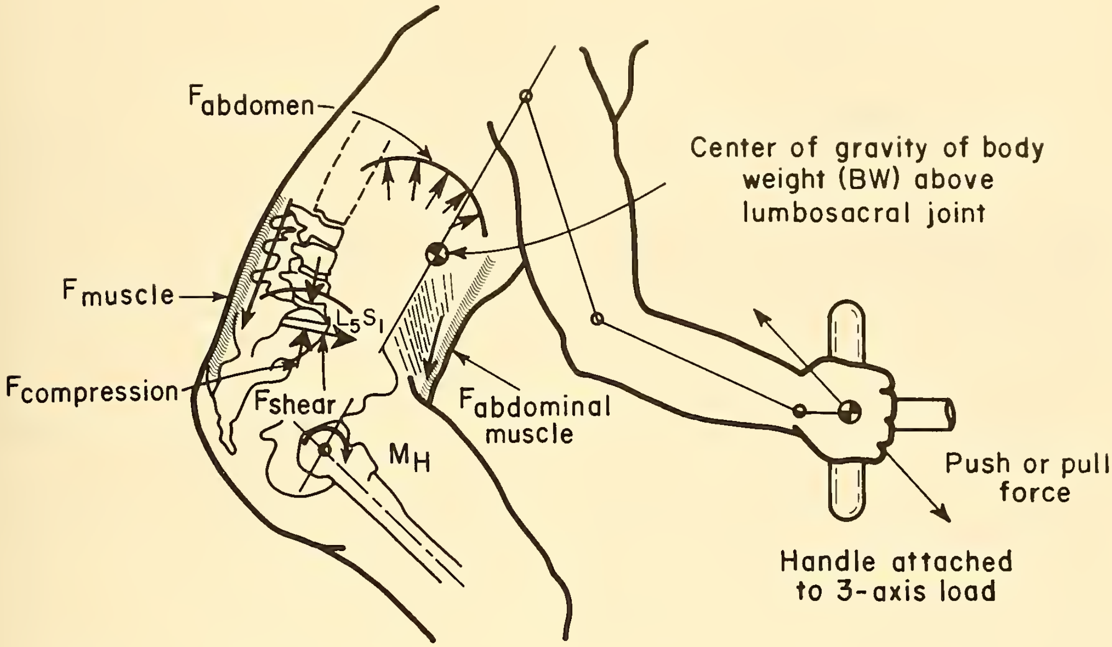

FIGURE 1. - Free body diagrom of the torso, showing voriobles used to colculote the compressive force ot L_5-S_1.

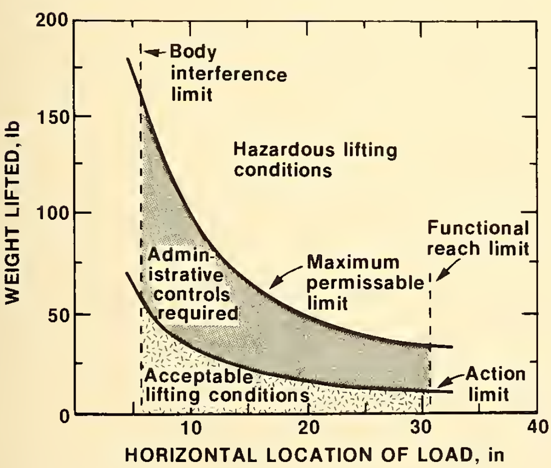

FIGURE 2. - Moximum weight versus horizontol locotion for infrequent lifts from floor-to-knuckle height (13).

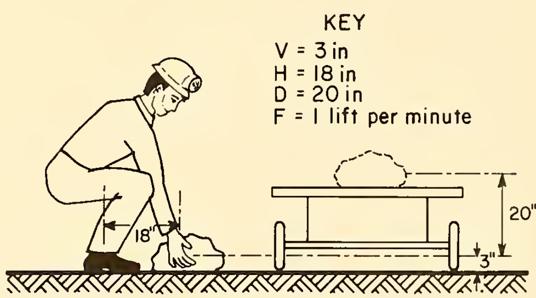

FIGURE 3. - Schemotic representotion of miner lifting moteriol onto o cort.

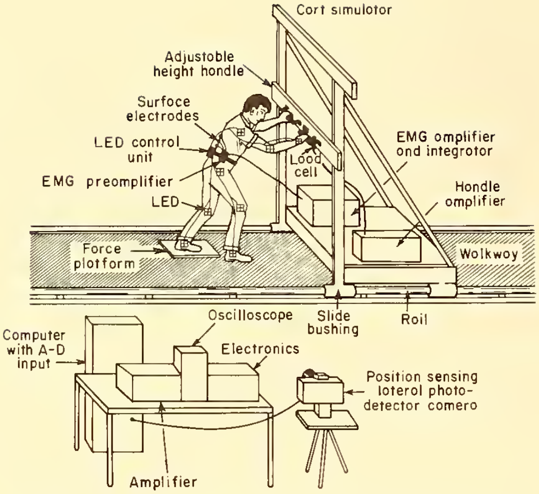

FIGURE 4. - Labaratary setup used ta callect data for the biadynamic push-pull madel.

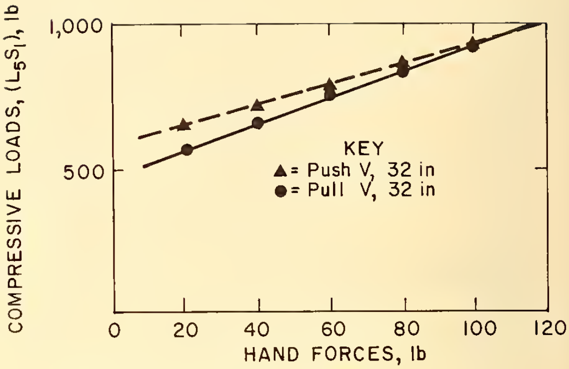

FIGURE 5. - Predicted L_5-S_1 compressive farces (8).

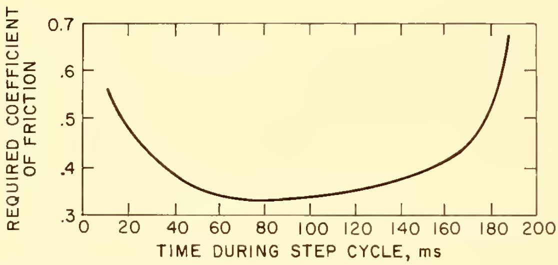

FIGURE 6. - Predicted required coefficient af frictian for ane faot at the shae-floar interface during a pushing task.

FIELD TESTING OF WORKERS INVOLVED IN MATERIAL HANDLING

By Karl H. E. Kroemer[1]

INTRODUCTION

Many industrial jobs require the worker to manipulate objects, position loads, and perform other physical activities that are usually understood as "lifting." The physical efforts involved in lifting often overload the physical capability of the people performing them, leading to very large numbers of job-related injuries and to very high costs in terms of lost time, compensation payments, and retraining of new personnel. Thus, industry is trying to either select people according to their strength, to train them so that they are able to perform stressful jobs, or to limit the loads to be moved by workers so that they will not be overstressed. For screening, reliable and valid tests are needed that assess the capability of an individual to manipulate loads. Relatedly, job requirements must be known regarding the type and magnitude of loads to be manipulated. Both tasks are interrelated because job requirements should match the operator's capability to perform the jobs, and vice verse.

Sponsored and coordinated by NIOSH, several researchers cooperated to determine the conditions that would either constitute safe or hazardous lifting requirements. A summary of the research and recommendations derived from it were published in the 1981 NIOSH "Work Practices Guide for Manual Lifting" (10).[2]

The guide utilizes weight to be lifted as the primary descriptor of the job requirements, but modifies this criterion by including the start and end points of the path of the lift, and by the frequency of lifting. These job requirements then, ideally, are matched to capabilities of the operators, or vice versa. Operator capabilities can be established using physiological, psychophysical, and biomechanical response variables. Among biomechanical test procedures, until recently only static tests were at hand. While well established and tested, these procedures obviously do not represent the dynamic requirements of industrial lifting, where work is usually performed with body and object in motion.

Psychophysical testing of a subject's dynamic capability for lifting was previously developed in the laboratories of Liberty Mutual Insurance Co. and at Texas Tech University. NIOSH sponsored research for the development of an industrial dynamic testing technique at Virginia Polytechnic Institute and State University. This work resulted in a new testing procedure and technique, called LIFTEST. This dynamic technique promises to be more reliable than static strength testing and appears to be more indicative of a person's actual lifting capability.

FITTING THE WORKER TO THE JOB VERSUS FITTING THE JOB TO THE WORKER

Manual material handling[3] produces the single largest percentage of compensable work injury in U.S. industry, constituting today one-fourth to one-third of all injuries. The cost to U.S. business is estimated between $4 and $20 billion annually (9, 10). Suffering of the injured and of their families cannot be expressed in dollar figures.

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[2]Underlined numbers in parentheses refer to items in the list of references at the end of this paper.

[3]This is often called lifting, although in its strict sense lifting refers exclusively to elevating an object from a lower level to a higher one.

The following three major avenues exist to reduce the frequency and severity of these injuries:

1. Screening of workers for their physical abilities to perform material handling.

2. Training of workers to perform material handling in a manner that avoids accidents.

3. Designing work task and work equipment so that workers will not be strained excessively by materials handling.

This presentation concentrates on screening of workers for their physical capabilities to handle material at work without overexertion.

After standard medical examinations were found ineffective for screening, more recently static muscular strength tests have been advocated (10). These assess isometric muscular strength of the human in discrete "frozen" body positions, primarily by measuring leg force, back force, and arm force (2). In comparing these scores via a biomechanical model of the human body with job requirements, or injury data in general, it was found that isometrically "stronger" workers have fewer and/or less severe injuries than isometrically "weaker" workers (10).

The effectiveness of a screening technique depends, to a large degree, on its ability to mimic the actual work requirements that may overexert human capabilities. Static strength testing suffers in particular from the fact that it is done with the worker being immobile while actual material handling usually involves motion.

Because of the apparent deficiency in the validity of static testing, NIOSH sponsored research (under contract 210-79-0041) to develop a dynamic technique to test individual capability for lifting. This work resulted in a testing procedure, called LIFTEST, that was found to be highly reliable, as well as quick and simple to administer, in laboratory experiments (6). While LIFTEST is apparently much more similar to actual material handling than static strength testing, its validity and effectiveness in screening workers for their capability to perform material handling tasks without injuries has yet to be assessed in a systematic manner.

INDIVIDUAL CAPABILITIES SHOULD EXCEED JOB DEMANDS

The premise of physical screening techniques is that human bodily capabilities will be measured and compared with related job requirements; the more tested capabilities exceed job demands, the "safer" the person-job match. In material handling, many of the critical injuries are related to the musculoskeletal system, particularly to the L_5-S_1 region of the spinal column. As the guide for manual lifting indicates, there is an epidemiological relationship between individual "strength" (as measured physiologically, biomechanically, or psychophysically) and job demands, with stronger persons being less susceptible to injuries than their weaker cohorts. Even other injuries related to materials handling such as lesions, abrasions, etc., show correspondence with the strength criterion (10).

ASSESSMENT OF INDIVIDUAL LIFT CAPABILITY

Current static biomechanical models of the human performing material handling include anthropometry, isometric muscle force (or torque) capabilities, the ability to withstand compression forces in the lower part of the lumbar spine, body posture descriptors, and work requirements (1). Unfortunately, the key ingredient, isometric muscle strength capability, is somewhat unrealistic because lifting and other material handling activities are performed with body and

load in motion and not in a static "frozen" condition. This discrepancy between static measurements and dynamic job requirements may explain why correlations between static strength and job performance capabilities are usually unsatisfactory for predictive-preventive purposes, being in the neighborhood of only 0.5 (7).

Researchers at the University of Michigan and at Texas Tech University developed static muscle strength tests and related their outcomes with incidences of physical overexertion in industries requiring material handling (3, 8). Both groups found that isometrically weaker persons suffered from a larger number of overexertion injuries than stronger subjects. However, some of the static strength tests showed practically no relationships to the probabilities of overexertion injuries. For example, of nine isometric strength tests applied by Keyserling (5), only four showed significant relations to the occurrences of musculoskeletal problems.

LIFTEST

Recognizing the problems of "unrealistic" static testing, NIOSH sponsored work to develop a dynamic testing procedure suitable for field application. This work was performed over a period of 2-yr, and resulted in the new technique called LIFTEST (6).

LIFTEST equipment consists essentially of a carriage that a person moves up and down within vertical guardrails. Variable weights are attached to the rear part of the carriage in such a manner that the subject is unable to see them. The person grasps the handles protruding from the carriage near floor height and lifts them, with carriage and weights attached, to her or his individual overhead reach height. Using a suitable sequence, the maximum weight that the individual can lift to overhead reach is determined within 2 or 3 min. In test-retest reliability experiments performed in the laboratory, 39 subjects could lift, on the average, 59.3 lb to overhead reach, with a standard deviation of 22.7 lb. This range indicates that the strength capabilities of the subjects employed were rather different. However, the subjects, whether weak or strong, showed a consistent low intra-individual variability of their individual scores in repeated tests. The average coefficient of variation was only 3.5 pct, compared with 13 pct in isometric strength tests (6). In rather similar "Factor X" tests with almost 600 subjects, male and female, the U.S. Air Force also found that such dynamic lift tests are much more reliable (i.e., less variable in repeated tests) than isometric muscle strength measurements.[4] Relatedly, isokinetic (i.e., constant speed) strength testing also showed relatively low correlations with isometric muscle strength testing (4). This strongly supports the notion that the dynamic LIFTEST can be used reliably to assess lift capability. What was not measured (and not intended to be measured) in the NIOSH-sponsored laboratory research was the validity of the test, that is, its relationship to actual lifting performance in industry. While having obvious "face-validity," the practical effectiveness of the LIFTEST procedure needs to be established in field tests. Interestingly enough, the U.S. Air Force used simulated "actual" lift tasks to validate their dynamic "Factor X" testing. The correlation between lift test results, and actual lift performance was about 0.9.[5] A correlation of 0.75 between isokinetic and actual lifting capability has been reported (4). These results strongly support the expectation that the LIFTEST procedure will be an efficient predictor of lifting capability on the job.

According to the premise discussed above, the ratio "strength available to strength required" would indicate the

[4]McDaniel, J. W. Personal Communication, Jan. 24, 1983.
[5]See footnote 4.

probability of an overexertion injury; a high ratio would make this probability small, a ratio close to unity would indicate a high probability. Used as a screening technique, one would avoid placing persons with a low ratio in jobs requiring such strength exertion, or reduce job requirements by administrative or engineering intervention. Persons with a high ratio could be employed in jobs requiring manual material handling with little danger of overexertion injuries.

ASSESSMENT OF JOB LIFTING REQUIREMENTS

The NIOSH guide provides a standardized procedure to assess the job requirements involved in material lifting tasks. The guide (10, p. 124) establishes three major categories of hazards in material handling. They are divided by the so-called "action limit" and the "maximum permissible limit." Below the action limit, no hazard to the individual is expected that would require engineering or administrative interaction. A "gray" zone exists between the action limit and the maximum permissible limit where suitable intervention methods are needed. These might mean worker screening-selection methods, and/or might involve engineering measures to reduce the worker's lift effort. Requirements above the maximum permissible limit are unacceptable.

The guide sets the maximum permissible limit numerically to be three times larger than the action limit. It appears reasonable to divide this zone between action and maximum permissible limits into two zones by doubling the action limit values. Hence, work requirements that fall below the doubled action limit would be less hazardous than those conditions falling between twice the action limit and maximum permissible limit values. Using such subdivision, one can categorize job demands in the following four areas: below action limit, between single- and double-action limit, between double-action limit and maximum permissible limit, and above maximum permissible limit.

According to the guide (10, p. 126), the following job variables primarily determine the job requirements: the initial starting point of the load, the end point of the lifting path, and the frequency of lifts per time unit performed. The individual contributions of these variables are expressed by an algebraic formula in the guide (10, p. 126). Start and end point are described by the height above the floor upon which the worker stands, and by the vertical distance away from the body of the worker. The frequency of lift is compared with a maximum frequency deemed suitable. The numerical values for these parameters are inserted into the formula given in the guide. Furthermore, the guide describes a measurement technique to determine the actual lift requirements at any given workplace.

COMPARING WORKER CAPABILITIES TO JOB REQUIREMENTS

Whereas the NIOSH guide provides a standard approach to establish job requirements, the LIFTEST procedure provides an equally convenient method to determine related physical capabilities of the worker. The LIFTEST regimen provides for a minimum load of 25 lb, and a maximum load of 100 lb to be employed for the establishment of overhead capability scores. With test weight increments of 5 lbs used, 18 different lift scores can be obtained, ranging from below 25 lb, at 25 lb increasing in steps of 5 lb to 100 lb, to exceeding 100 lb. (The 5-lb increment values can be combined to larger units, such as 10 lb, in order to reduce the number of lift capability assessments as convenient.)

In summary, the guide provides a standardized procedure to assess lift requirements imposed by the job. LIFTEST provides a reliable procedure to assess dynamic individual lift capabilities.

LIFTEST PROCEDURE FIELD STUDIES

The general aim of a field study being organized by the author is to assess the effectiveness of the LIFTEST procedure as a screening technique for reducing severity and frequency of overexertion injuries resulting from manual material movement, particularly lifting.

The specific aims of this study are

1. Measure individual lifting capabilities, via the LIFTEST procedure, approximately 15,000 workers doing material handling.

2. Monitor overexertion and other related injury events of these workers over a 3-yr period.

3. Determine job lift strains, as needed.

4. Compare injury statistics with performance in LIFTESTs.

5. Assess the effectiveness of the LIFTEST procedure as a screening technique based on the results of aims 1 through 4.

METHODS

Several large industries in Virginia, North Carolina, and Tennessee have consented to participate in this study. Others are invited to participate.

The currently participating industries employ about 50,000 hourly paid persons. Of these workers, approximately 30 pct have jobs that include material handling. If these 15,000 workers have a related accident-injury rate during the 3-yr research period of approximately 10 pct (_5_, _10_), approximately 1,500 cases would be present. Even if a dropout rate of one-third (which would be very high indeed) existed in the subject population, approximately 1,000 cases present in the study would constitute a solid statistical basis.

In order to establish the effectivenss of the LIFTEST procedure, the following steps will be taken:

1. _Measure individual lifting capabilities of approximately 15,000 workers involved in material handling._ The cooperating industries will identify, internally, in accordance with existing management-labor practices and agreements, jobs with material handling requirements and the persons either incumbent in the jobs, being transferred to them, or to be hired for them. These persons will be measured, usually in conjunction with a routine physical examination, in their LIFTEST performance by the companies' medical staff. In order to ensure uniformness and consistency in the application of the LIFTEST procedure, the initial equipment setup and training of the staff applying the tests will be provided by the author and his team.

Test results will become part of the medical record kept by the industries in accordance with their existing safeguarding practices.

2. _Monitor overexertion and other related injuries of workers over a 3-yr period._ Participating industries will monitor injuries related to material handling according to the industry-established practices. This assures that anonymity and privacy of the worker records remain intact, such as they would be without this investigation.

3. _Determine job lift requirements._ The author and his team will, in cooperation with industry personnel, and in accordance with local management-labor practices, determine the actual lifting requirements of jobs that have a potential for, or a record of, lifting-related overexertions. This will be done according to reference 10.

The assessment of job requirements will be independent from the person actually occupying the job. Hence, personal records of the worker will not be provided to the investigators but will remain in custody of the industry.

4. Compare injury statistics with LIFTEST performance. The participating companies will compare accident severity and frequency, according to ANSI and OSHA standards, with performance on LIFTEST. Where the accident circumstances are not obvious, the industry will cooperate with the investigators in the determination of job requirements prevailing at the injury time (step 3). With the four categories of NIOSH-defined job requirements and 18 LIFTEST procedure-performance steps, incidents can be recorded on a 4 by 18 matrix. (If required, the NIOSH job requirement categories can be further subdivided and/or the number of LIFTEST performance score categories be reduced, as described above.). Only anonymous information regarding incidence and test performance will be received by the investigators.

5. Establish effectiveness of the LIFTEST procedure as a screening technique. Based on the data collected in steps 1 through 4, correlations between LIFTEST performance and injuries will be established. In a first step, LIFTEST performance will be compared with injury severity and frequency, following common practice in industrial and injury statistics. In this case, the actual job requirements are not considered in detail. As a second step, detailed comparison of job requirements with LIFTEST performance will be done, based on the results of the specific job requirement assessments. This will identify correlations between general and specific job requirements (such as lift frequency, initial position of the load, final position of the load, etc.) and LIFTEST performance.

STATISTICS

The statistical procedures are simple and straightforward, using the industry-common ANSI Z16 technique. This facilitates the cooperation with industry.

As in previous experiments (5), the following chi-square formula to test the significance of differences between incident rates and test performance will also be used.

$$\chi^2_{m-1} = \sum_{i=1}^{m} \frac{(E_i - O_i)^2}{E_i}, \qquad (1)$$

where χ^2_{m-1} = test statistic with (m-1) degree of freedom,

m = number of LIFTEST score categories being compared,

E_i = expected number of incidents in category i, based on exposure,

O_i = observed number of incidents in category i,

and $i = 1, 2, 3, \ldots m$.

The values of E_i are computed with the following equation:

$$E_i = \frac{H_i}{H_t} \times O_r, \qquad (2)$$

where H_i = hours of exposure in category i,

H_t = total hours of exposure across all categories,

or O_r = total number of observed incidents across all categories.

CONCLUSION

While the basic solution is to design jobs to fit the worker, training and, in particular, selection of individuals for safe material handling are also indispensable. Regarding screening, the testing should be "realistic," that is, represent actual job demands. Dynamic tests appear to be more suitable than static muscle strength testing. Procedures to develop and apply such dynamic testing are at hand.

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LIFTING CAPACITY DETERMINATION

By M. M. Ayoub,[1] J. L. Selan,[2] W. Karwowski,[3] and H. P. R. Rao[4]

ABSTRACT

Given the large number of tasks in the mining industry that require manual materials handling (MMH) and the enormous costs associated with musculoskeletal injuries resulting from MMH, job design and employee placement procedures for MMH tasks in the mining industry would be beneficial. A major step in establishing these procedures is the determination of the lifting capacity of the individual or population performing a given lifting task. The three primary approaches used to determine lifting capacity are the biomechanical approach, the physiological approach, and the psychophysical approach. This paper proposes the use of the psychophysical approach to determine lifting capacity owing to the fact that it attempts to combine the biomechanical and physiological stresses present in all lifting tasks under a measure of perceived stress. A mathematical, fuzzy-sets-based model of lifting capacity is presented that demonstrates that the combining of acceptability measure for psychophysical stress. Advantages of the fuzzy-sets-based model and examples of its use are given.

INTRODUCTION

Manual materials handling (MMH) activities, and in particular manual lifting, are recognized as a major hazard to the safety and health of industrial workers (17)[5] and a majorcost to industry (10). Recent evidence (19) supports the notion that numerous tasks in the mining industry involve manual lifting, and as such could be helped by improved job design and employee placement procedures in order that job demands can be controlled to stay within individual capacities. A major step in the establishment of such procedures is the determination of the lifting capacity of the individual or population performing these jobs. It has been noted by Karwowski (11) that no OSHA regulations exist regarding the maximum acceptable weight of lift; this being due in part to the fact that existing recommendations are based on different methodological approaches assessing different categories of stresses in MMH activities. The three primary approaches to determine lifting capacity are (1) the biomechanical approach, (2) the physiological approach, and (3) the psychophysical approach.

BIOMECHANICAL APPROACH

In general, biomechanics determines what a person can physically do. Biomechanical models attempt to establish the physical stresses imposed on the musculoskeletal system during a lifting action; these stresses serve as the criteria upon which capacity of lift is based. These physical stresses include reaction forces and torques on various joints of the body (4) and compressive and shear forces on the lower back

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5-6). The low back, in particular the L_4-L_5 and L_5-S_1 disks of the lower back, is especially considered as a basis for load lifting limits owing to the excessively high forces produced on the low back when lifting (3, 18, 22) and the large number of back injuries arising from manual lifting.

The ultimate goal of the biomechanical approach is to set limits on these physical stresses imposed during lifting and then determine the load-lifting capacity based on these limits. Towards this goal, both static and dynamic models of lifting capacity have been developed based on the biomechanical approach. Static biomechanical models, such as those developed by Chaffin (4), assume that the lifting action is performed slowly and smoothly such that forces due to the acceleration can be neglected. Dynamic models, such as those developed by Fischer (7), El-Bassoussi (6), Ayoub (3), and Muth (16, pp. 96-109), provide data for analyses in the form of time-displacement relationships of the body segments (kinematic analysis) and the forces and torques involved in the motion (kinetic analysis).

Figure 1, based on the dynamic biomechanical model developed by El-Bassoussi (6) and Ayoub (3), presents lifting capacity guidelines developed using the biomechanical approach. The figure shows three different lifting regions based on compression on the spine. Weights of lift producing compressive forces of less than 1,100 lb are considered acceptable (i.e., minimal risk of injury to worker). Lifting tasks producing compressive forces of 1,540 lb or more are considered hazardous and should be redesigned. The region between these two values falls under the area of administrative control. As is also indicated in the figure, if the center of gravity (CG) of a load from the spine is 20 in, an acceptable weight of load would be 25 lb, and a weight of load of 69 lb or more would produce excessive compressive forces on the spine. The constant compression lines were developed using the concept of a biomechanical equivalent (22) in the form of

$$BE = H \times (w),$$

where BE = biomechanical equivalent, pound-inch,

H = horizontal distance of the CG of the load from the spine, inches,

and W = weight of the load, pounds.

The model allows the calculation of the compressive and shearing forces on the L_5-S_1 disk during the time course of a lifting movement in the sagittal plane from floor to a 2.5-ft height. The output of the model include the reactive forces and torques at several joints involved in the motion.

PHYSIOLOGICAL APPROACH

The physiological approach may use several criteria, such as oxygen consumption, heart rate, pulmonary ventilation volume, or percent of physical work capacity, as indices of heaviness of work performed. Generally, the criterion used is the energy expenditure while lifting loads.

Oxygen consumption is generally measured to estimate the energy expenditure required by a lifting task. The measurement of the physiological demands can also be related to an individual's maximum aerobic capacity in order to determine what percent of that capacity a given lifting task requires.

As with the biomechanical approach, the goal of the physiological approach is to develop limits using metabolic energy expenditure criteria and then determine lifting capacity based on the chosen criteria limits. Several prediction models of metabolic energy expenditure for lifting tasks have been developed (4, 8-9). Based on the physiological approach, it has been concluded that, for a young male, the 8-h average metabolic rate should not exceed 5 kcal/min or 33 pct of

the individual's maximum aerobic capacity, and heart rate should not exceed 110 to 115 beats per minute (20). Figure 2, based on the model reported by Garg (11), shows the effect of frequency of lift (lifts per minute) and lifting technique on the weight of load that can be lifted to maintain an energy expenditure of 5 kcal/min.

PSYCHOPHYSICAL APPROACH

The third method employed to determine lifting capacity is the psychophysical approach. Psychophysics deals with the relationship between human sensations and their physical stimuli; this relationship best being described by a power function (21). The use of psychophysics in lifting tasks requires the subject to adjust the weight of load according to his or her own perception of effort such that the lifting task does not result in overexertion or excessive fatigue. The final weight decided upon by the subject represents the maximum acceptable weight of lift for the given job conditions (frequency of lift, height of lift, container size, etc.).

Several lifting capacity prediction models using the psychophysical approach have been developed (13-15). The major limitation with these models has been that they are applicable to only one or two lifting ranges and only one frequency of lift. Ayoub (2) developed lifting capacity prediction models that were more flexible than the previously developed models in that six ranges of lift and different work paces were accommodated by the model. Table 1 presents the lifting capacity norms for male and female industrial workers developed by Ayoub (2). Figure 3 presents capacity norms adjusted for load size and frequency of lift developed by the senior author. The capacity norms are given by the formula

$$LC = rv \times a \times b,$$

where LC = capacity of lift, pounds,

rv = reference value at one lift per minute,

a = percent multiplier for frequency,

and b = percent multiplier for load size

TABLE 1. - Distribution of maximum weights of lift acceptable to male and female industrial workers[1] (corrected for one lift per minute and load size of 18 in), pounds

Range of lift	Sex	Mean	SD	Percent of population				
				95	75	50	25	5
Floor to knuckle...........	Male...	61.17	16.87	33.43	49.62	61.17	72.71	88.90
	Female.	37.12	6.76	26.00	32.50	37.12	41.73	48.20
Floor to shoulder..........	Male...	51.12	12.11	31.29	42.91	51.21	59.50	71.13
	Female.	31.08	6.54	20.32	26.60	31.08	35.56	41.83
Floor to reach.............	Male...	49.12	11.20	30.69	41.45	49.12	56.79	67.54
	Female.	28.14	5.41	19.24	24.41	28.14	31.84	37.04
Knuckle to shoulder........	Male...	57.75	14.67	33.33	47.42	57.47	67.52	81.60
	Female.	31.97	6.55	21.19	27.48	31.97	36.45	42.74
Knuckle to reach...........	Male...	53.54	10.70	35.93	46.21	53.54	60.87	71.14
	Female.	26.22	4.86	18.22	22.89	26.22	29.55	34.21
Shoulder to reach..........	Male...	43.62	10.45	26.43	36.46	42.62	50.77	60.81
	Female.	25.78	4.17	18.92	22.92	25.78	28.63	32.64

SD Standard deviation. [1]Assuming a normal distribution.

COMPARISON OF THE THREE APPROACHES

It is the assertion of this paper that the psychophysical approach is the appropriate single approach to use to determine lifting capacity. The problem with the use of the biomechanical approach or the physiological approach alone is that both biomechanical and physiological stresses are usually present in almost all lifting tasks. Using the aforementioned physiologically based guidelines proposed by Snook (20), it is intuitively obvious that an individual could stay within the recommended physiological limits by lifting a very heavy load at a low frequency of lift. However, such a procedure would violate lifting capacity recommendations based on biomechanical criteria. Conversely, lifting capacity models based solely on biomechanical criteria are wholly inadequate in dealing with the effects of repetitive lifting on the cumulative physical stresses imposed on the body.

The discrepancies encountered by the use of biomechanical or physiological criteria alone in the determination of lifting capacity become evident when comparing the lifting guidelines presented in figure 1 (using the biomechanical approach) and the lifting guidelines presented in figure 2 (using the physiological approach). Although attempting to make comparisons between these two approaches is difficult, the aforementioned problems associated with using only a biomechanical or physiological criterion can be made more evident. For example, a weight of load of 88.2 lb is acceptable at low frequencies of lift using the physiological approach, whereas this same weight of load significantly exceeds the acceptable lifting region recommended when using the biomechanical approach. In fact, in situations where the horizontal distance of the center of gravity of the load from the spine exceeds approximately 12 in, a weight of load of 88.2 lb is considered hazardous based on the biomechanical criteria.

In general MMH recommendations based on biomechanical models suggest lifting light loads at higher frequencies of lift, whereas physiological models suggest the lifting of heavier loads at a reduced frequency of lift. Also, it is often assumed by researcher in the area of MMH that only biomechanical criteria need to be considered if the frequency of lift is low, and only physiological criteria need to be considered for higher frequencies of lift. This could be a dangerous oversimplification.

Lifting is a task of a complex nature such that it cannot be fully explained using only physiological or biomechanical criteria. Both physiological and biomechanical stresses, among others, are present in every lifting task and, as such, the need exists for a means of determining lifting capacity that can accommodate both of these everpresent stresses. The virtue of the psychophysical approach is that it attempts to combine the stresses, including the biomechanical and physiological stresses present in the lifting task under a measure of perceived stress.

COMBINED STRESS VERSUS PSYCHOPHYSICAL STRESS

The psychophysical approach is based on the assumption that the biomechanical and physiological stresses are integrated or combined under the measure of perceived stress. No theoretical method has existed in the past for combining the biomechanical and physiological stresses to determine their relationship with the psycholphysical stress. However, a recent model of lifting capacity developed and reported by Karwowski (11-12) has provided a means by which the relationship between the combined effects of biomechanical and physiological stresses and the perceived stress determined psychophysically can be explained.

Karwowski (11) hypothesized that a combination of the acceptability of biomechanical and physiological stresses

imposed during manual lifting leads to an overall measure of the lifting task acceptability, expressed by the acceptability of the psychophysical stress. Toward the testing of this hypothesis, Karwowski utilized a fuzzy sets theory [for a thorough explanation of the concept and fundamentals of fuzzy sets theory refer to Zadeh (23)].

Karwowski (11) developed a fuzzy set model from which an acceptability measure for biomechanical stress and an acceptability measure for physiological stress could be integrated into a measure of combined stress. Following this, mathematical procedures stemming from fuzzy sets theory were used to determine the relationship between the maximum acceptable weight of lift from the psychophysical and combined standpoints. Based on these mathematical procedures, Karwowski (11) concluded that the maximum acceptable weight of lift based on a psychophysical criterion appears to be the result of the integration of the biomechanical and physiological stresses imposed by the lifting task.

Figure 4 shows the relationship between the acceptability measures of the combined stress versus the acceptability measures of the psychophysical stress. The combined stress is determined by taking the algebraic product of the acceptability measures of the biomechanical and physiological stress. The acceptability measure is determined using membership functions developed by Karwowski (11) for the biomechanical, physiological, and psychophysical stress. The degree of membership can be any value ranging from 0 to 1, with 0 representing nonmembership in a set, and 1 indicating total membership in the set. The stresses given a value of 1 (i.e., are totally acceptable in terms of stress imposed) were selected based on past research in the areas of acceptable biomechanical, physiological, and psychophysical stresses. For example, the membership function for the acceptability of the psychophysical stress was based on the lifting capacity norms presented in figure 1.

One of the advantages presented by the fuzzy-sets-based model is that it allows for the determination of lifting capacity, and consequently allows for the design of a lifting task, without the necessity of performing any psychophysical experiments. By determining the acceptability measure of the biomechanical and physiological stresses imposed on the individual while lifting a specified weight of load and then combining these two stresses into a single category, the level of psychophysical stress that is likely to occur for this particular lifting task can be assessed. In addition, predictive models already exist whereby the physiological and biomechanical stresses can be determined without extensive experimentation. Oxygen consumption can be predicted using equations such as those developed by Garg (9) or Asfour (1). Biomechanical stresses can be predicted using a dynamic biomechanical model such as the one developed by El-Bassoussi (6).

Using an example from Karwowski (11), consider a task in which an individual lifts 75 lb from floor to knuckle height at a frequency of three lifts per minutes using a squat lifting technique (i.e., back straight, bent at knees). Given these task conditions, oxygen consumption would be approximately 0.886 L/min and the biomechanical stress imposed would be 1,690 lb, with the acceptability measures for the physiological and biomechanical stress based on the fuzzy sets model being 0.7929 and 0.5233, respectively. The membership functions for the biomechanical and physiological stress from which the acceptability measures were determined are given in figures 5 and 6, respectively. The combined stress is then determined to be 0.4150 (by taking the algebraic product of the acceptability measures of the biomechanical and physiological stress). The hypothetical capacity norm can then be determined by multiplying the 75 lb by the acceptability measure for the combined stress. Based on this product, it can be concluded that a weight of load of 31.13 lb would represent a totally acceptable weight for the given task.

To further illustrate the relationship between the acceptability measures for the combined stress and the psychophysical stress, the psychophysical stress calculated by the fuzzy sets model was 0.4552. As can be seen in figure 7, the capacity norm based on the psychophysical methodology is 34.14 lb. The difference between this norm and the hypothetical capacity norm derived from the combined stress is 3.01 lb (9.13 pct). This represents more evidence that the psychophysical stress is a combination of the physiological and biomechanical stresses imposed on the individual while lifting.

SUMMARY

Figure 8 presents a model of lifting performance that summarizes the proposals made in this paper. First, the ultimate goal and purpose of lifting capacity determination is to stay within individual capacity when designing total job demand. By accomplishing this, the percentage of the population able to perform the task increases and the injuries associated with people exceeding or approaching their physical capabilities diminishes. Second, in order to match individual capacity with total job demand, the lifting capacity of workers must be determined. This paper hopefully has proposed that the psychophysically determined lifting capacity should be used as the basis for job design and placement of workers.

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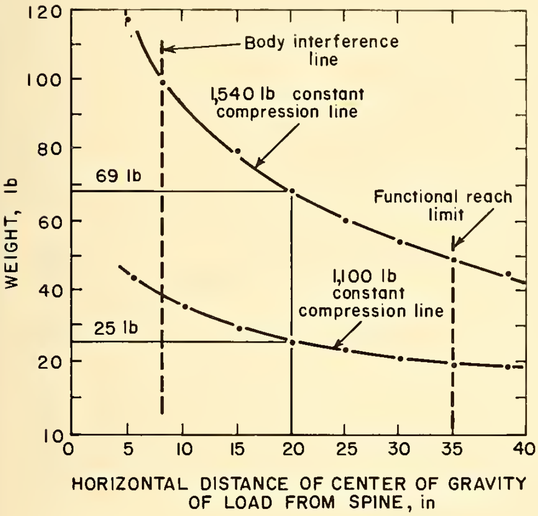

FIGURE 1. - Maximum weight versus horizontal distance from spine based on 1,100 lb and 1,540 lb of compression on spine, respectively.

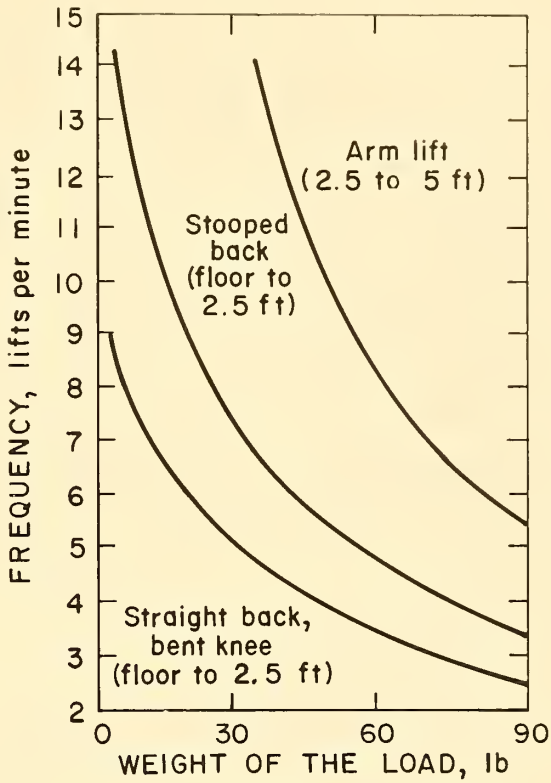

FIGURE 2. - Effect of lifting technique and frequency of lift on weight of load that can be lifted to maintain metabolic energy expenditure of 5 kcal/min.

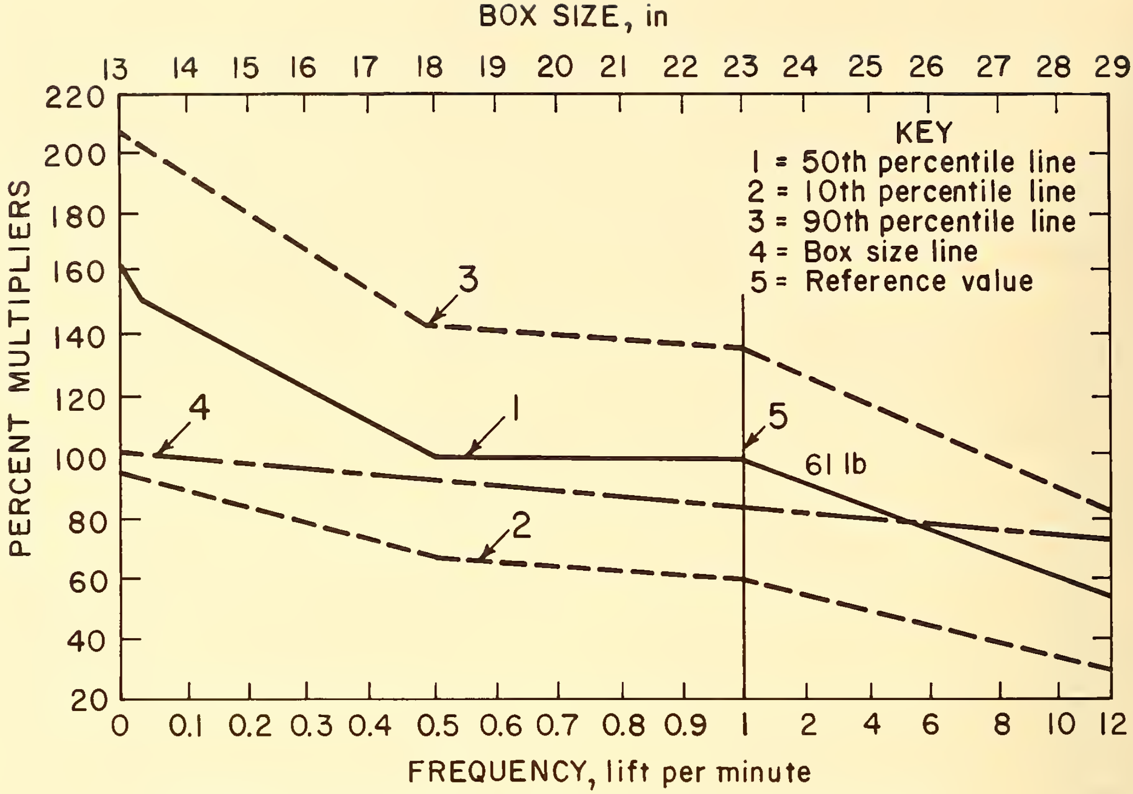

FIGURE 3. - Lifting capacity norms for males (floor-to-knuckle height).

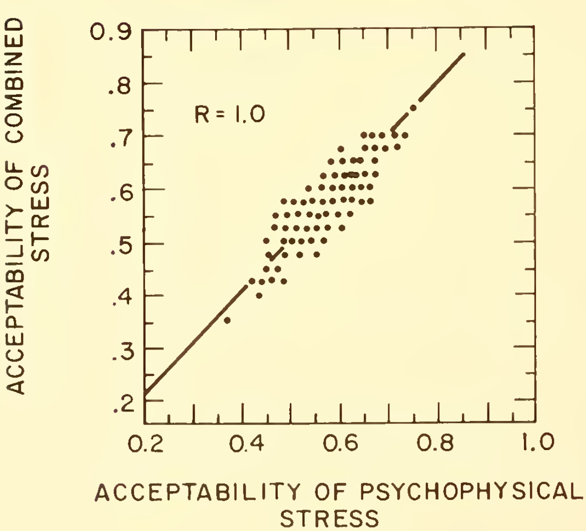

FIGURE 4. - Acceptability of the combined biomechanical and physiological stress versus the acceptability of the psychophysical stress.

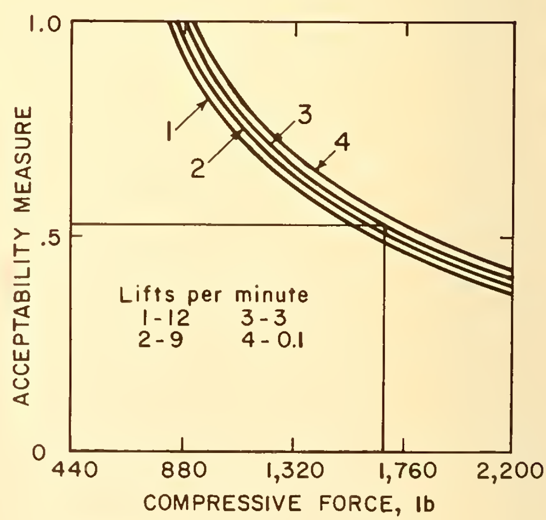

FIGURE 5. - Membership function for biomechanical stress.

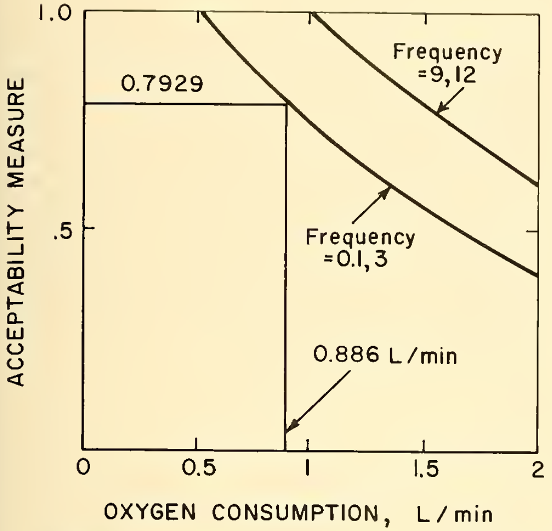

FIGURE 6. - Membership function for physiological stress.

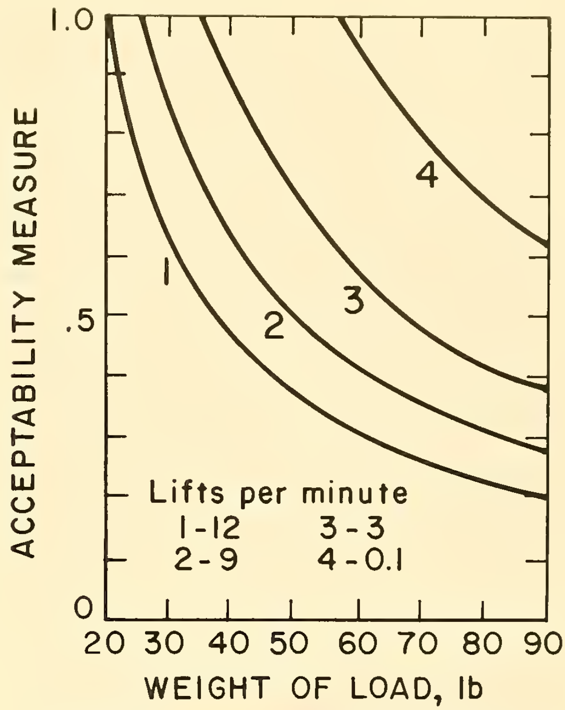

FIGURE 7. - Membership function of psychophysical stress.

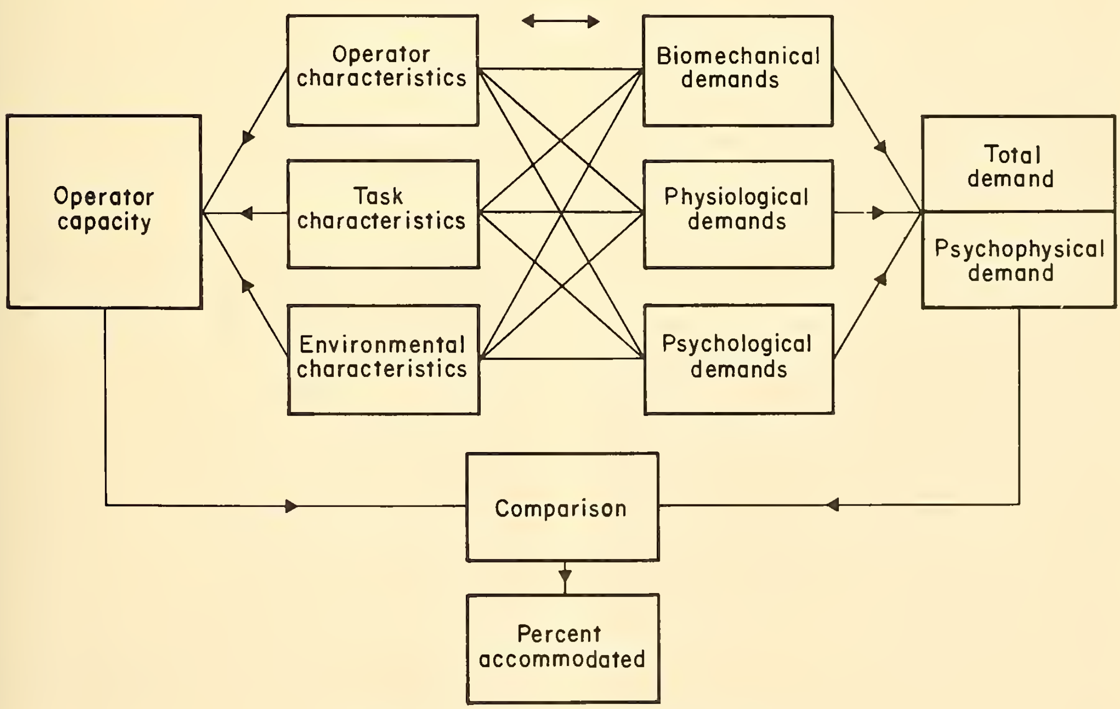

FIGURE 8. - A model of lifting performance.

JOB DESIGN FOR MANUAL MATERIAL HANDLING TASKS

By M. M. Ayoub,[1] J. L. Selan,[2] and H. P. R. Rao[3]

ABSTRACT

A procedure for job design of and employee placement into manual material handling (MMH) tasks based on job demand and employee capacity is discussed. The first step involves an extensive analysis of selected jobs in terms of injury data (nature of injury, number of lost workdays, etc.) and lifting requirements of the job (weight, frequency, range of lift, etc.). The measure of job stress to be used is a job severity index (JSI). The JSI is the ratio of the job demand to the capacity of the person or population working under the job conditions, expressed as the time frequency weighted average of the maximum weight required by each task divided by the smallest lifting capacity given the lifting task conditions. The JSI provides a means to measure job severity and to define the relationship between this measure and an acceptable measure of injury potential. Procedures for job design and employee placement based on the JSI are discussed and examples are given.

INTRODUCTION

A large number of work injuries in the industrial arena arise either directly or indirectly from the handling and/ or mishandling of materials. National Safety Council (8)[4] statistics indicate that 27 pct of all industrial injuries were associated with MMH; this percentage equaled 590,000 injuries with a total cost of approximately $10.4 billion. More important, the number of MMH-related injuries continues to increase (670,000 injuries in 1980 based on National Safety Council estimates) despite improved medical care, increased automation in industry, and more extensive use of preemployment examinations.

More imposing than the increase in the number of work injuries is the increase in the cost of these injuries. The economic costs associated with MMH-related injuries include medical costs, lost worktime, insurance-related costs, loss of material and property damage, lost wages, training cost of a new worker, and administration costs. The relationship between these costs and back injuries over a 33-yr span (1957-90, projected) is exponential as shown in figure 1 [based on National Safety Council estimates; from Aghazadeh (1)]. The alarming rate of increase in the cost of back injuries has also been reported by Snook (11). During the 1938-65 period, the number of compensable back injuries increased by 11.4 pct while the average cost per back injury increased by approximately 400 pct.

The mining industry contains several jobs in which MMH activities, in particular manual lifting, constitute a major component of the job (10). A listing of some of these jobs is given below.

Jackleg drilling

Stoper drilling

Tmbering

Steel set construction

Concrete construction

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[4]Underlined numbers in parentheses refer to items in the list of references at the end of this paper.

Gunite and shotcreting

Rock dusting

Loading powder bags

Ventilation and pipe installation

Track installation and maintenance

Given this prevalence of MMH activities in the mining industry, it would not be surprising to find a large number of injuries including back injuries among miners. It has been reported (8) that in Pennsylvania 4.8 pct of all compensable back injuries were from miners. A study presently being conducted for the Bureau of Mines (5) also indicates indirectly the presence of worker injuries in the mining industry. As part of the ongoing study (5), isometric strength tests are being conducted on miners, provided at the time of the test, the miner is not suffering from a back injury of any kind. Over 10 pct of all miners in the study have reported back injuries (although it has not been determined in the study whether the injuries were directly work related). It has been noted in another recent study conducted for the Bureau of Mines (2), that the heavy lifting demands and awkward postures imposed in low-coal mining (seam height <48 in) may result in an increased probability of back injuries.

Nordby (9) reported that, out of 8 million low-back problems that occurred in 1974, 200,000 required surgical treatment. Because of the severity, frequency, and cost of MMH-related injuries, procedures for job design of and employee placement into MMH tasks need to be seriously considered, properly developed, and applied. Such procedures should be based on job demands and worker capacity, and need to be validated in the work environment. The means to determine worker capacity has been discussed elsewhere (6), therefore, only a brief summary will be presented here.

The variables affecting lifting capacity fall into three general categories: worker, task, and environmental. Worker variables include such factors as body weight, sex, age, training, etc. Task variables include frequency of lift, range of lift, load size, and others. Some significant environmental variables include heat stress, floor stability, traction, etc. There are three different bases for determining lifting capacity. These are the biomechanical basis, the physiological basis, and the psychophysical basis. For the biomechanical basis, estimates are made of the stresses imposed on the musculoskeletal system while lifting. Limits for these stresses are established from which the capacity or loads to be lifted can then be estimated. Similarly, the physiological basis sets upper limits based on metabolic or cardiovascular criteria (e.g., percent of physical work capacity) and then determines lifting capacity as some percentage of the physiological indice(s).

As noted by Ayoub (6), the problem with using either the biomechanical or physiological approach is that both stresses are present in any lifting activity. The third basis, psychophysical, attempts to combine the biomechanical and physiological stresses under a measure of perceived stress on the part of the individual. The measure of lifting capacity used in conjunction with psychophysical methods is the "maximum acceptable" or "maximum safe weight of lift," defined as the maximum weight an individual feels he or she could lift repeatedly without undue stress or overtiring.

The purpose of this paper is to propose the use of the JSI developed by Ayoub (3) as a means to define the relationship between an acceptable measure of injury potential and a measure of job severity. Also, this paper proposes the use of the procedures outlined by Ayoub (3), based on the work done with the JSI, for job design of and employee placement into MMH tasks based on job parameters and employee capacity. The JSI will be defined in the following section, and in the final section the job design-employee placement procedures based on the JSI will be discussed.

THE JOB SEVERITY INDEX

DEVELOPMENT

The JSI conceptually is the ratio of a measure of job demand to a measure of the capacity of the person or population performing the job under the job conditions. A large JSI represents a relatively stressful job.

The job demands are determined using a detailed job description procedure. The initial step in the job description procedure is to determine the average length of the work week, the average length of the workday or shift, the number of shifts per day, and a general written description of the job. This information is primarily used to determine the average job exposure time of the employees.

The next step is to describe each job in terms of actual weight of lift, frequency of lift, load size, and range of lift. Because many jobs display a lack of constant parameters (e.g., several frequencies of lift are required), each job is divided into a number of component tasks such that each task can be described with constant or near constant parameters. Thus, each job is described as a series of lifting tasks described in terms of frequency of lift, range of lift, etc.

Range of lift is defined in terms of lift initiation level and lift termination level. The load size or dimension is defined in terms of inches along a line perpendicular to the frontal plane of the body of the person doing the lifting. Lifting frequency is defined as the average number of lifts per minute required by the particular task.

The JSI is designed specifically for those jobs requiring lifting as a substantial portion of the job. As such, MMH activities, such as carrying, pushing, or pulling, are excluded from analysis. However, the job description procedure can be applied to lowering tasks (which were found by Ayoub (3) to occur in significant amounts in most jobs requiring lifting).

The measure of lifting capacity used by the JSI is the maximum acceptable weight of lift determined based on psychophysical data. As noted, maximum acceptable weight of lift is defined as the maximum weight an individual feels he or she can lift repeatedly without undue stress or overtiring. Ayoub (3) developed a set of mathematical models to predict the maximum acceptable weight of lift based on various conditions of lifting frequency, load size, and range of lift, coupled with a few strength and anthropometric measurements. These regression models are presented in table 1. One model was developed for each of the following ranges of lift:

Floor to knuckle (F-K)

Floor to shoulder (F-S)

Floor to full reach (F-R)

Knuckle to shoulder (K-S)

Knuckle to full reach (K-R)

Shoulder to full reach (S-R)

These models have R_2 values of between 0.85 and 0.877. It should be noted that these equations predict the sum of the maximum acceptable weight of lift plus body weight. The sex code is 0 for males and 1 for females. The weight code is 0 if body weight is below the median and 1 if body weight is above the median for the male or female population. The median body weights for females and males are 138 and 170 lb, respectively. All strength variables are in pounds, age is in years, endurance in minutes, and anthropometric variables are in centimeters.

TABLE 1. - Prediction models for maximum acceptable weight of lift plus body weight for both males and females

Lifting range	Constant term	Sex code	Weight code	Arm strength	Age	Shoulder height	Back strength	Abdominal depth	Dynamic endurance
F-K....	-72.165	-28.334	24.243	0.143	-0.553	1.225	0.056	4.914	1.757
F-S....	-145.412	-16.165	11.928	.185	-.597	1.438	.077	6.472	2.608
F-R....	-41.267	-19.453	16.176	.210	-.892	.759	.068	6.220	1.426
K-S....	-55.160	-18.542	11.700	.265	-.606	.768	.105	6.290	1.415
K-R....	-79.193	-18.917	17.273	.297	-.499	.092	.018	5.154	2.120
S-R....	-37.439	-19.584	20.352	.096	-.592	.886	.099	4.731	1.090

F-K Floor to knuckle. F-R Floor to full reach. K-R Knuckle to full reach.
F-S Floor to shoulder. K-S Knuckle to shoulder. S-R Shoulder to full reach.

As noted, the JSI is a function of the ratio of job demands to worker capacity. Specifically, the JSI is the time and frequency weighted average of the maximum weight required by each task divided by the smallest capacity of those associated with lifting ranges required by each task. The JSI is stated algebraically as follows:

$$JSI = \sum_{i=1}^{n} \left(\frac{Hours_i}{Hours_t} \times \frac{Days_i}{Days_t} \right) \sum_{j=1}^{m_i} \left(\frac{F_j}{F_i} \times \frac{WT_j}{CAP_j} \right),$$

where n = number of sub-task groups,

m_i = number of task in group i,

$Days_i$ = exposure days per week for group i,

$Days_t$ = total days per week for job,

$Hours_i$ = exposure hours per day for group i,

$Hours_t$ = number of hours per day that a job is performed,

F_j = lifting frequency for task j,

F_i = total lifting frequency for group i,

WT_j = maximum weight of lift required by task j,

and CAP_j = the smallest applicable maximum acceptable weight of lift adjusted for frequency of lift and load size.

FIELD VALIDATION

Field validation of the JSI was conducted by Ayoub in 1978 and 1982 (3-4). The purpose of both studies was to attempt to define the relationship between MMH injury and the JSI. In general, the methodology employed in both studies was to evaluate the stress levels of industrial subjects working in different lifting jobs and relate the JSI to the injury rates experienced by the same group of subjects.

The first step in the field study phase was the selection of jobs for analysis. Selection was based on the extent that the job involved MMH and specifically lifting (e.g., a MMH job involving pushing would be excluded). Taking the 1978 and 1982 studies (3-4) together, a total of 101 jobs involving 385 male and 68 female industrial workers from 2 private companies and governmental agencies were used in the field validation.

The selected jobs were analyzed in terms of lifting requirements of the job (procedure and parameters used were discussed earlier) and in terms of injury data. Information collected describing injuries included injury type, injury cause (lifting or nonlifting), number of days lost, medical expenses, wages paid

during lost workdays, worker's compensation paid, and extraordinary expenses. Injury type classifications are given below.

Type 1. Musculoskeletal injuries to the back.

Type 2. Musculoskeletal injuries to other body parts.

Type 3. Surface tissue injuries due to impact.

Type 4. Other surface tissue injuries.

Type 5. Miscellaneous injuries.

Individual JSI's were calculated for each industrial subject. The resulting JSI values were grouped into four ranges: JSI values greater than 0.00 and equal to or less than 0.75, greater than 0.75 and equal to or less than 1.5, greater than 1.5 and equal to or less than 2.25, and greater than 2.25. The injury data and exposure times for the subjects in each group were then compiled and summed.

Figure 2 shows the relationship between JSI and the number of back injuries sustained per 100 full-time-equivalent (FTE) employees (equal to 200,000 exposure hours) for the 1978 and 1982 studies (3-4) combined. Figure 3 shows the relationship between JSI and the number of disabling (one or more lost days) back injuries sustained per 100 FTE employees for the combined studies. Figure 4 shows the relationship between JSI and the severity (number of days lost per disabling back injury) of disabling back injuries. Figure 5 shows the relationship between JSI and total direct injury expense (defined as the sum of medical expenses, wages paid during lost workdays, and worker's compensation) using data from the 1982 study (4). For most of the parameters, substantial increases occurred at JSI levels equal to or greater than 1.5, and for a number of parameters (most notably severity of disabling back injuries) there occurred another substantial increase at JSI levels of 2.25 or above.

Also determined was a stress measure for each of the 101 jobs selected for analysis. Following determination of the stress measure, each job was placed into one of the three following categories: Jobs that overstressed less than or equal to 5 pct of the sample population, jobs that overstressed more than 5 pct but less than 75 pct of the sample population, and jobs that overstressed more than 75 pct of the sample population. That proportion of the sample population for each job with JSI values greater than 1.5 was defined as the percentage overstressed for the job.

Table 2 shows the injury and cost statistics calculated for each job stress category for the 1978 and 1982 studies (3-4), respectively. As percentage overstressed increased, both injury rates and costs increased.

TABLE 2. - Number of back injuries, number of disabling back injuries, days lost per disabling back injury, and total expenses observed in various job stress categories

(Per 100 full-time-equivalent employees (200,000 exposure hours) caused by lifting)

Population overstressed,[1] pct	Back	Disabling	Days lost	Total expense	Population overstressed,[1] pct	Back	Disabling	Days lost	Total expense
1978 DATA, 63 JOBS					1982 DATA, 38 JOBS				
≤5............	5.33	5.44	2.3	NA	≤5............	4.18	0	0	NA
>5, ≤75.......	5.59	1.93	9.5	NA	>5, ≤75.......	16.79	12.60	15.6	$35,092
>75...........	12.04	8.76	14.1	NA	>75...........	23.84	17.03	13.4	$36,337

NA Not available.

[1]Defined as that proportion of the sample population for each job with JSI values greater than 1.5.

SIGNIFICANCE OF JOB SEVERITY INDEX

The JSI can be used as a tool for job design and employee placement using the relationship between JSI injury frequency and/or job severity. For job design, the following procedure can be followed:

Step 1. Describe the job as a series of tasks, each having a weight distribution, average frequency, and ranges of lift.

Step 2. Select an acceptable injury frequency based on company policy.

Step 3. Select the population for which the job is to be designed (for example, 95 pct of the population, females, etc.).

Step 4. Using step 2, determine the corresponding JSI from the available data. (Such data have been collected by Ayoub (3), see table 3.)

Step 5. For each task (a) select the smallest of the predicted lifting capacities using the appropriate equation from table 1 (e.g., if a task requires three lifting ranges, select the smallest capacity of the three) and (b) calculate the maximum design weight of lift for a task using the JSI equation.

Step 6. If for a given task, the required weight of lift is above the maximum designed weight of lift, the job should be redesigned in terms of required range of lift, frequency of lift, etc.

To use the JSI for employee placement, the following procedure should be followed:

Step 1. Collect the information and make the measurements necessary to predict the individual's lifting capacity for each of the six lifting ranges using the predictive models given in table 1. As noted, this information includes sex, weight, age, arm strength, shoulder height, back strength, abdominal depth, and dynamic endurance.

Step 2. Determine the JSI for the person if placed at a given job using the JSI equation.

Step 3. Use this JSI to determine the expected injury frequency rate if placed on that job. Table 3 can again be referenced.

Step 4. Make the screening and placement decision based upon the acceptability of the injury frequency rate determined in step 3.

TABLE 3. - Expected frequency of total injuries[1] as a function of JSI (3), warehousing industry

Frequency expected[2]	JSI	Frequency expected[2]	JSI
28.........	0	50.........	0.8032
30.........	.0489	60.........	1.1803
32.........	.1244	70.........	1.5574
34.........	.1998	80.........	1.9345
36.........	.2752	90.........	2.3116
38.........	.3506	100........	2.6888
40.........	.4261	120........	3.4430
42.........	.5015	150........	4.5754
44.........	.5769	200........	6.4599
46.........	.6523	232........	7.6449
48.........	.7277		

[1]Sum of the 5 injury type classifications.

[2]Per 100 full-time-equivalent employees (200,000 exposure hours).

The JSI has been successfully utilized in a number of industrial settings. As an example of the practical application of the JSI, Liles (7) performed an analysis of selected jobs involving MMH for Western Electric Corp. The analysis results for each job were presented in a three-part summary and are presented in tables 4 through 6. Table 4 presents the job information necessary for the JSI calculations. Table 5 gives the JSI's of a large representative population of people working in MMH activities. This portion of the analysis results was conducted under the assumption that the large

TABLE 4. - Job description information for job 99 (7)

	Task 1	Task 2
Maximum weight.....lb..	50	30
Lifting frequency......	1.0000	1.0000
Maximum box size...ft..	5	2
Load center of gravity:		
Initial.............	9	8
Terminal............	15	8
Load height, in:		
Initial.............	12-22	25-35
Terminal............	25-35	30-40
Task:		
Hours................	8	8
Days.................	5	5

TABLE 5. - Statistics for representative population assumed to be working in job 99 (7)

	Population percentile	JSI	
		Male	Female
Task 1.........	95	3.70	50.00
	50	1.27	2.61
	5	.84	1.29
Task 2.........	95	2.22	30.00
	50	.76	1.56
	5	.50	.78

TABLE 6. - Actual JSI values for persons working in job 99 (7)

Subject	JSI
Female..........................	2.1021
Male............................	.8787

size of the assumed population would provide a better indicator of the JSI than the small group of people actually working on the jobs. Finally, table 6 presents the JSI values for the people actually working at the particular job.

In comparing the data presented in tables 5 and 6, it should be noted that the JSI values for the representative population of MMH workers (table 5) are significantly larger than for the actual population working in job 99. This would imply that an employee placement procedure of at least a subliminal level is being carried out. Unfortunately for industry, this nonformalized method of employee placement is generally of a hit-or-miss nature, and the misses in industry often surface as injured workers. The use of a formalized, empirically based employee placement procedure (rather than, for example, the supervisor deciding a worker looks strong enough to perform the job) such as the JSI could potentially reduce the number of injuries caused by the wrong worker being placed on the wrong job.

Acceptable and unacceptable weights of lift as determined through use of the JSI can be compared with lifting guidelines predicted using other procedures. Figure 6 compares the limits for a floor-to-knuckle lift at various lifting frequencies obtained using the JSI and using the protocol recommended in the NIOSH guide (12) for manual lifting. The maximum permissible limit (MPL) and action limit (AL) lines generated using the NIOSH equations correspond roughly with the 2.25 and 1.125 JSI lines, respectively, in that lifting tasks above 2.25 or the MPL fall in the unacceptable range (i.e., require engineering controls), tasks below 1.125 or the AL represent a nominal safety risk, and tasks falling between the criterion limits (1.125-2.25, AL-MPL) require administrative control. It is apparent that the AL and, to a lesser extent, the MPL are more conservative than the corresponding JSI lines; this being particularly true for higher frequencies of lift.

SUMMARY

It can be said that the ratio of job demand to the capacity of the worker does affect the frequency and severity of injuries incurred during MMH activities. Use of the JSI provides a means to control these injuries through redesign of demand tasks and/or (as a last resort) better placement of workers. Because of the presence of MMH activities in the mining industry, the JSI has the potential to reduce the frequency and severity of MMH-related injuries in this industrial area.

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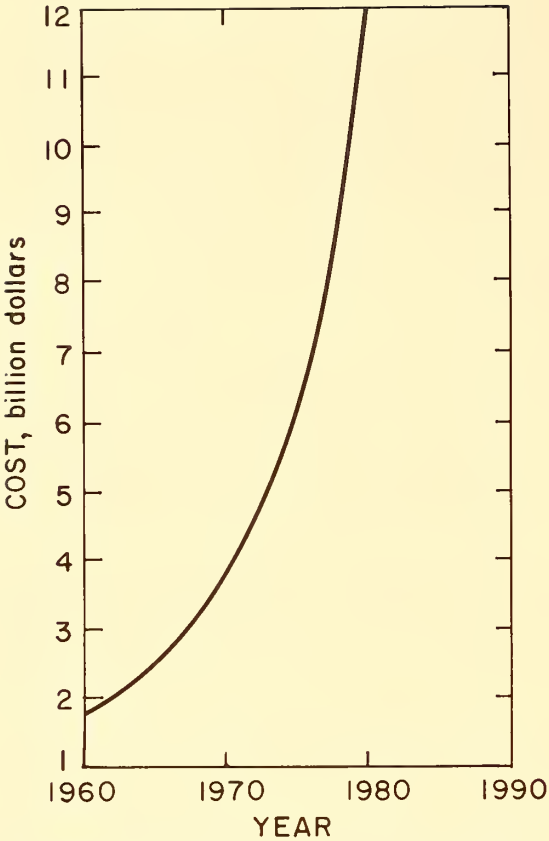

FIGURE 1. - Cost of trunk injuries over time (1).

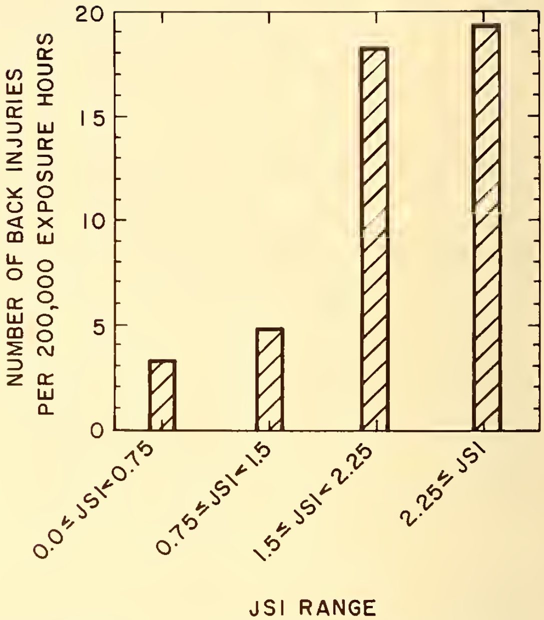

FIGURE 2. - The incidence of back injuries caused by lifting versus JSI.

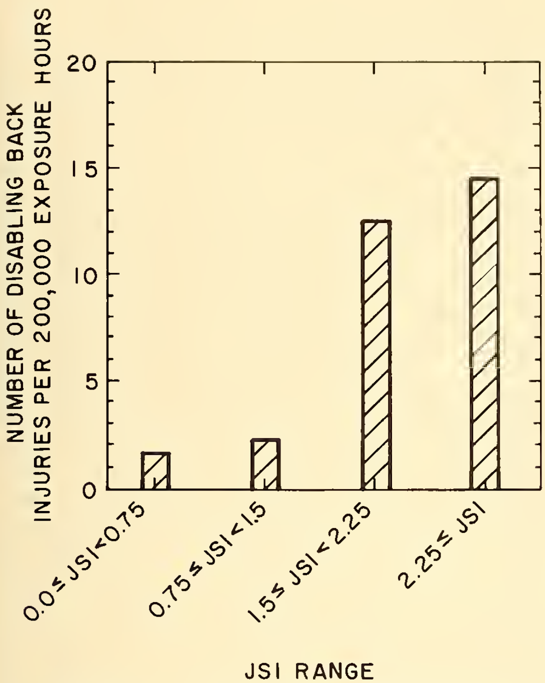

FIGURE 3. - The incidence of disabling back injuries caused by lifting versus JSI.

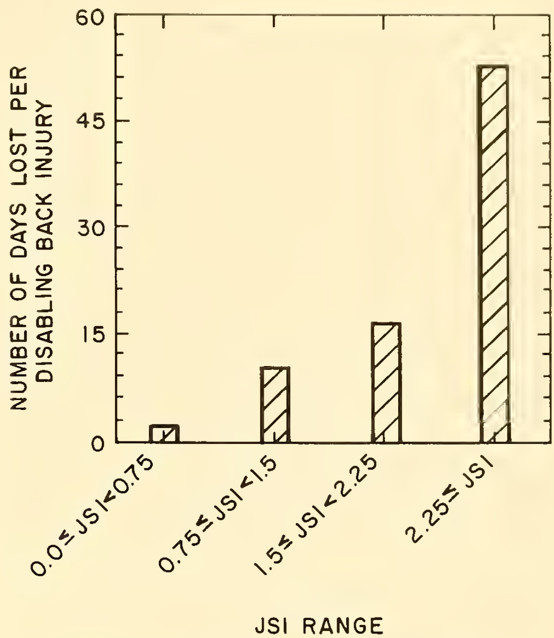

FIGURE 4. - The severity of disabling back injuries caused by lifting versus JSI.

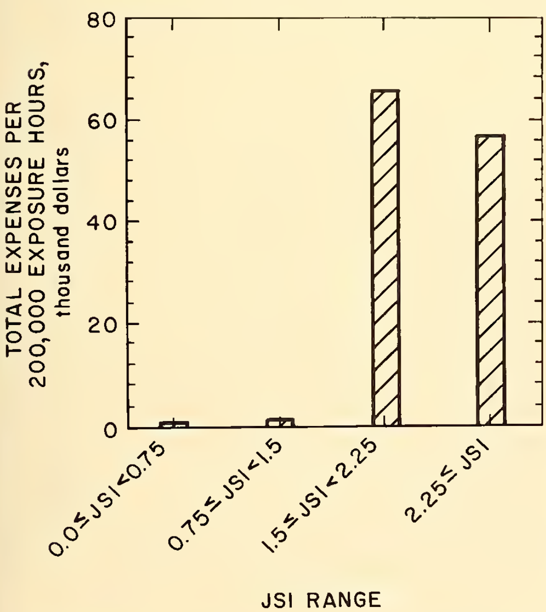

FIGURE 5. - The total expense of back injuries caused by lifting versus JSI.

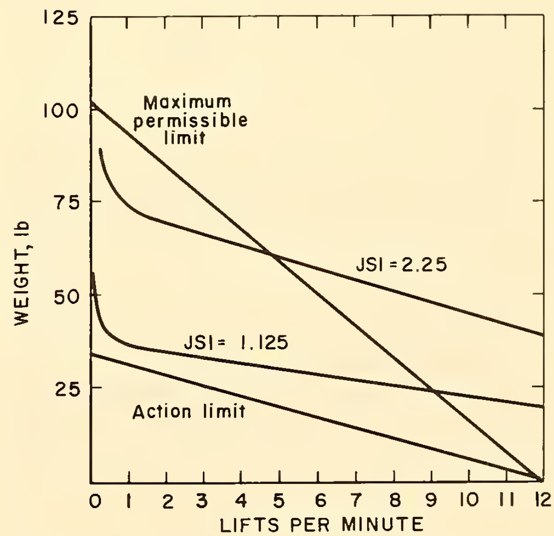

FIGURE 6. - Comparison of lifting guides based on JSI versus NIOSH (12) lifting guidelines.

BACK INJURIES AND MAINTENANCE MATERIAL HANDLING IN LOW-SEAM COAL MINES

By Ernest J. Conway[1] and William W. Elliott[2]

INTRODUCTION

Accidents associated with the handling of materials and supplies have traditionally accounted for a large percentage of all industrial lost-time injuries. The National Safety Council reports that this accident category is responsible for at least 25 pct of all industrial accidents. In the mining industry, an even higher percentage of materials handling injuries are noted. As table 1 suggests, these statistics are relatively consistent across various types of mining operations. Somewhat higher percentages, however, are noted for underground coal mines and for metal processing plants.

TABLE 1. - Materials handling injuries by industry by work location, January-March 1982[1]

	Handling injuries	Lost time injuries	
		Total	pct
Coal mines:			
Underground........	1,115	3,211	34.7
Surface............	175	628	28.0
Preparation plant..	68	233	29.0
Metal mines:			
Underground........	93	337	27.5
Surface............	51	150	34.0
Mills..............	71	193	36.7
Total or percent.	1,573	4,752	33.1

[1]Mine Injuries and Worktime Quarterly, January-March, 1982, U.S. Department of Labor, Mine Safety and Health Administration.

Table 2 summarizes manual materials handling injuries in 26 mines at several points in the mine supply cycle. It is noted that the largest single source of injury involves the movement of supplies and components from the surface to the point of use in the mine. This function, however, may involve handling of the same material two, three, or more times prior to reaching the point of use. The second largest category, which accounts for approximately 26 pct of all injuries, occurs during the actual use of the materials in mine maintenance or equipment repair activities. These are the accidents to be discussed in this paper. For purposes of the following discussion, materials handling shall be defined as the lifting, pushing, pulling, or shoveling of materials or components used during equipment maintenance or during mine maintenance activities.

TABLE 2. - Analysis of in-mine material handling injuries for 26 mines

Handling mode	Injuries, pct
On-section manual handling of equipment and or supplies during production shift......	11.2
Supply movement from surface to point of use..............	49.5
Section move: Movement between working sections.......	13.0
Equipment maintenance: During maintenance shift............	16.3
Mine maintenance and handling on maintenance shift.........	10.0
Total....................	100.0

[1]Vice president, Canyon Research Corp., Westlake Village, CA.
[2]Fire systems engineer, Santa Barbara Research Center, Subsidiary of Hughes Aircraft Co., Santa Barbara, CA.

ACCIDENT REPORT ANALYSIS

In an effort to define the magnitude of the materials handling injury problem in underground coal mines, an analysis was performed of over 75,000 accident reports collected and reported in the Mine Safety and Health Administration Health and Safety Analysis Center (HSAC) data base for a 3-yr period.[3] This review resulted in the identification of 15,416 cases that reportedly involved materials handling activities. These materials handling accident reports were then sorted into the following four categories:

1. Part of body injured

2. Type of accident.

3. Source of injury

4. Nature of injury

Table 3 summarizes the 15,416 injury reports by part of body affected. It is observed that over 39 pct of these reported injuries involved the middle and lower back. This category represents a larger percentage of materials of handling injuries than the next six elements combined.

Table 3 also summarizes the same 15,416 cases by type of accident. It is noted that the largest single accident category is overexertion while lifting. This frequently involves the lifting of a component (e.g., a shuttle car drive motor) or mine supplies (e.g., rock dust bags, etc.) from the ground prior to use. Likewise, it is noted that overexertion pulling accounts for another 20.6 pct of the total injuries. Combined, overexertion type accidents account for more than half of all the injuries.

[3]Ongoing BuMines contract H0113018; for info., contact R. L. Unger, Pittsburgh Res. Center, Pittsburgh, PA.

TABLE 3. - Ranking of underground mine maintenance material handling injuries

Rank	Element	pct
	PART OF BODY	
1........	Back....................	39.7
2........	Finger..................	18.3
3........	Hand....................	4.9
4........	Foot....................	4.8
5........	Hips....................	4.0
6........	Knee....................	3.6
7........	Shoulders...............	3.1
8........	Eyes....................	2.8
9........	Multiple parts..........	1.8
10.......	Wrist...................	1.5
11.......	Neck....................	1.5
12.......	Chest...................	1.4
13.......	Leg, NEC................	1.4
14.......	Arm, NEC................	1.3
15.......	Abdomen.................	1.3
16.......	Head, NEC...............	1.0
17.......	Toes....................	1.0
18.......	Ankle...................	1.0
NAp......	Other...................	<1.0
	ACCIDENT TYPE	
1........	Overexert, lift.........	31.0
2........	Falling object..........	14.3
3........	Overexert, NEC..........	13.1
4........	Caught, NEC.............	8.8
5........	Overexert, pull.........	7.5
6........	Struck by, NEC..........	6.7
7........	Stationary object.......	6.5
8........	Caught, moving and stationary.	3.3
9........	Flying object...........	2.6
10.......	Rolling object..........	1.2
11.......	Overexert, wield........	1.2
NAp......	Other...................	<1.0

NAp Not applicable.
NEC Not elsewhere classified.

When the materials handling accidents are sorted on the basis of the source of injury, an interesting distribution is observed (table 4). As table 4 suggests, a broad spectrum of components and materials are involved in the maintenance-related handling injuries. As will be discussed later, many of these elements

would probably not have resulted in injuries if they were handled on the surface instead of in the mine. This type of distribution suggests that what is handled may not be as important as where and how it is handled.

TABLE 4. - Underground maintenance handling injuries summarized by source of injury

Rank	Element	pct
1........	Metal, NEC..............	13.8
2........	Timber posts, cap.......	12.8
3........	Broken rock, ore........	8.9
4........	Electrical conduit......	7.2
5........	Steel rail..............	4.6
6........	Belt conveyor...........	3.6
7........	Metal components........	3.5
8........	Cement products.........	2.9
9........	Wood items, NEC.........	2.5
10.......	Jacks...................	2.5
11.......	Rock bolts..............	2.4
12.......	Bags....................	2.3
13.......	Barrels, drum...........	2.1
14.......	Chains, ropes...........	1.9
15.......	Underground mine machine	1.9
16.......	Miscellaneous, NEC......	1.8
17.......	Containers, NEC.........	1.6
18.......	Cribbing................	1.6
19.......	Container, NEC..........	1.6
20.......	Blocking................	1.4
21.......	Pumps, fans, NEC........	1.3

NEC Not elsewhere classified.

Perhaps the most revealing summary is presented in table 5. This table summarizes the underground materials handling injuries on the basis of the number of days lost. Not only do back injuries account for the largest percentage of the injuries, but they account for an even larger percentage of days lost from work. This suggests that back injuries are somewhat more serious than other types of injuries.

In an effort to identify the specific task being performed by the miner at the time of the maintenance handling injury, a second series of analyses were performed for the narrative description of 5,376 HSAC cases. These cases involved only in-mine equipment or mine maintenance tasks. These accidents were sorted into the following categories:

1. Lifting or lowering
2. Carrying
3. Maneuvering
4. Other activity

TABLE 5. - Summary of 1978-80 underground coal mine material handling accidents, HSAC data

Part of body injured	Injuries		Injuries involving days lost	
	Total	pct	Total	pct
Head.....	889	5.8	487	4.0
Neck.....	230	1.5	201	1.6
Shoulders	474	3.1	400	3.3
Arms.....	451	2.9	335	2.7
Wrists...	226	1.5	165	1.4
Hands....	752	4.9	512	4.2
Fingers..	2,813	18.3	1,673	13.7
Trunk....	589	3.8	494	4.1
Back.....	6,119	39.7	5,606	46.0
Hips.....	617	4.0	400	3.3
Legs.....	1,079	7.0	920	7.6
Feet and toes....	880	5.7	736	6.0
Other....	291	1.8	253	2.1
Total..	15,410	100.0	12,182	100.0

Table 6 identifies the miner's activity and the items being handled at the time of the accident for equipment maintenance tasks. It is pointed out that lifting and lowering of components accounted for the majority of all the days lost. It is also noted that oil drums and grease cans, machine parts and tools are the most frequently involved items.

Table 6 also summarizes the miner's activity at the time of the accident by the material handled during mine maintenance activities. It is observed that lifting-lowering of track rails and timbers are involved with the largest number of days lost from work. This can be anticipated since rails and timbers have relatively high unit weights and are awkward to handle. Unfortunately, track laying and timber handling is traditionally accomplished manually using only a few simple handtools.

TABLE 6. - 1978-80 underground coal mine material accidents, summarized by activity and item being handled

Activity	Item	Days lost
DURING EQUIPMENT MAINTENANCE ACCIDENTS		
Lifting-lowering....	Oil drum, grease can, hydraulic oil.......	3,629
Do................	Machine part, tool........................	2,249
Other activity......	.....do..................................	2,182
Lifting-lowering....	Pump, motor, gearbox, wheel unit..........	1,749
Do................	Cover plate, X-P cover....................	1,639
Do................	Tire......................................	1,127
Do................	Toolbox...................................	1,070
Maneuvering.........	Machine part, tool........................	692
Carrying............	Oil drum, grease can, hydraulic oil.......	559
Dropping............	Machine part, tool........................	537
Carrying............	Pump, motor, gearbox, wheel unit..........	490
Other activity......	Tire......................................	434
Do................	Oil drum, grease can, hydraulic oil.......	349
Maneuvering.........	Pump, motor, gearbox, wheel unit..........	334
Other activity......	Cover plate, X-P cover....................	314
Carrying............	Machine part, tool........................	301
Other activity......	Pump, motor, gearbox, wheel unit..........	289
DURING MINE MAINTENANCE ACCIDENTS		
Lifting-lowering....	Track rail................................	1,828
Do................	Timber, cribbing, ties....................	1,355
Do................	Crossbar, header..........................	783
Other activity......	Timber, cribbing, ties....................	643
Maneuvering.........	Track rail................................	487
Lifting-lowering....	Other.....................................	425
Other activity......	Track rail................................	388
Do................	Crossbar, header..........................	372
Lifting-lowering....	Stopping block............................	327
Dropping............	Track rail................................	319
Carrying............	Other.....................................	236
Do................	Timber, cribbing, ties....................	224
Other activity......	Stopping block............................	211
Dropping............	Timber, cribbing, ties....................	150
Do................	Stopping block............................	149
Lifting-lowering....	Rock dust, cement bag.....................	148

The above analysis has pointed out that

1. A majority of the in-mine injuries involve materials handling activities and account for about 34 pct of all lost-time injuries.

2. About 40 pct of these injuries involve the middle or lower back.

3. Over 30 pct of the injuries resulted from overexertion while lifting or lowering objects.

CONTRIBUTING FACTOR IDENTIFICATION

Through examination of these accident data, it is possible to identify factors contributing to these injuries. By looking at some of the biomechanical limitations of the human body, it is possible to identify areas where mechanization of materials handling tasks and/or changes in procedures can minimize the associated risk to mine personnel. This is particularly important for lower seam height mines which tend to have more severe material handling related back injuries.[4]

[4]Work cited in footnote 3.

Why are there relatively higher numbers and more severe back injuries in lower seam mines? There are several factors involved. The most important one, however, is the fact that the spine is designed to carry a maximum load when the miner is standing in an erect, upright position. In fact, the cervical, thoracic, and lumbar curves in the spine are designed to center the load being lifted (including the body weight of the individual) between the ball and the heel of the foot. In the fully erect position, the human spine typically can safely handle up to 100 pct of the persons's body weight for short periods of time.[5]

When the spine is in other than the full erect position, however, the load that it can safely handle decreases sharply. This is the result of--

1. The load not being evenly distributed across the vertebra and the intervertebral disk.

2. The muscles being strained simply supporting the weight of the upper torso, arms, and head.

3. The ligaments and tendons being strained supporting the upper body weight and guiding the body's motion.

More specifically, when the miner is bending forward (as in a 48- to 60-in seam height), the muscles of the back and stomach, which are normally used to maintain balance, must now support the weight of the head, upper torso, and arms from a biomechanically disadvantaged position. This amounts to a substantial amount of weight if you consider that

1. The average head (without the neck) weighs 20 to 30 lb.

2. The average arm up to the shoulder weighs 12 to 15 lbs.

3. The upper torso minus the head, neck, and arms weighs 70 to 90 lb.

The back and stomach muscles of the typical 190-lb miner are supporting somewhat over 100 lb of "dead" upper body weight when he or she leans forward approximately 45°. This moment of force must be borne by the lower spine and typically acts on the lumbrosacral joint. This simply means that the body itself (spine, muscles, and ligaments) is incapable of handling as much nonbody weight as when the person is standing in a full upright position. In an improper work position, a load weighing only 30 lb combined with the weight of the upper body components may produce a torque on the lower spine exceeding 300 in·lb. The latter is the lifting equivalent of quite a severe lifting task. Hence, depending upon the miner's build and physical condition, from 50 to 90 pct of the back's muscle strength may be used just to support the upper body weight. This suggests that a person can only safely lift considerably less than 50 pct of the weight that could be lifted in a normal erect position. This percentage is reduced even further if

1. The miner is sitting on his or her knees or buttocks, thus eliminating the shock-abosorbing effects of the knees and ankles.

2. The lifting task requires movement of the object from one side of the body to the other with the feet or knees (e.g., in a kneeling position) in a fixed position.

3. The lifting task requires the transporting of the center of mass away from the body.

4. The size of the object moves the center of mass of the person-object away from the body's own natural center of gravity.

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[5]U.S. Department of Health and Human Services. Work Practices Guide for Manual Lifting. NIOSH Pub. 81-122, 1981, 183 pp.; PB 82-178-948.

Research has shown that a majority of the low-back injuries actually occur upon release of a heavy load rather than at the moment it is picked up. The reason for this is that when a load is lifted the stress induced to the human body is distributed over time (e.g., 0.75 to 1.50 sec). When the same load is released, separation may take place in as little as 40 sec or one-twentieth of the time required to place the load on the spine. This results from

1. Extreme stress induced by muscle action required to reestablish the body's center of balance.

2. Sharply increased musculoskeletal loading on the vertebra while attempting to regain balance.

To make matters worse, the closer the miner's body is to the floor (i.e., stooped forward 90°), the greater the musculoskeletal stress.

As table 7 illustrates, many of the materials handling tasks performed during mine or equipment maintenance involve the lifting or handling of items that exceed safe lifting weights for persons not in a full upright position.

TABLE 7. - Weight of frequently handled components

Description	Unit weight, lb	Frequency	Tools
EQUIPMENT MAINTENANCE			
Major component replacement........	200-2,000	Monthly...	Jacks, come-alongs.
Component replacement..............	50- 200	Weekly....	Handtools.
Minor component replacement........	5- 50	Daily.....	Do.
Lubrication and servicing..........	5- 50	...do.....	Pails, 5-gal cans.
Move workers' tool.................	50- 200	Monthly...	Toolbox.
Repair by welding..................	50- 200	Daily.....	Cutting and welding equipment.
Change tire........................	50- 200	Weekly....	Jack.
Repair electrical cable............	1- 5	Daily.....	Handtools.
Access permissible enclosure.......	50- 200	...do.....	Do.
MINE MAINTENANCE			
Set props and crossbars............	200- 500	0 to 20 per day.	Saw, axe.
Build stopping walls...............	50- 100	2 per day.	Axe.
Build ventilation doors............	5- 50	Monthly...	Handtools
Build cribs........................	50- 100	Daily.....	Axe.
Install track......................	100-1,000	Monthly...	Handtools, sledgehammer, pry bars.
Build overcasts....................	200- 500	Semiannual	Handtools, axe, sledgehammer, pry bars.
Install water pipes, pumps.........	50- 100	Weekly....	Handtools.
Install electrical power boxes.....	200- 500	Semiannual	Come-alongs, handtools, scoop.
Rock dust back entries.............	50- 100	Daily.....	None.
Clean up rib trash, rock falls, etc.	5- 50	...do.....	Shovel, scoop.
Build plank roadways through wet areas.	50- 100	Semiannual	Scoop.

SUMMARY

What are the implications of these findings for materials handling in lower seam mines? First, with this understanding of the material handling tasks that must be performed and the limitations of the human spine, innovative approaches to the materials handling problem can be sought. As reported in another paper in this proceedings, the Bureau of Mines is currently developing a number of innovative handling devices.

Secondly, improved materials handling procedures and practices need to be developed. The straight-back lifting technique is simply not effective in mines where the miner cannot stand upright. Research is needed to find an alternative approach. Likewise, procedures that better utilize the tools and equipment found in the mine environment to do the materials handling need to be identified, thereby eliminating stress on the miner's back.

Third, equipment used in mines needs to be designed so that it can be properly and safely maintained in the restrictive mine environment. The size and weight of supplies and materials used in mine maintenance needs to be reduced to ensure that they can be "safely" handled by the miner.

Finally, every miner must understand the limitations of the human back and he or she must take the precautions necessary to prevent injury.

TRAINING PROCEDURES TO REDUCE LOW BACK INJURIES

By Nancy C. Selby[1]

ABSTRACT

Many back injuries can be avoided, as can chronic back pain. However, individuals need to have enough information to be able to understand how to protect themselves. Safety information must be presented in a manner that is relative to individuals' environment and educational level. Since most back injuries do not occur on the job, first aid and home activities must be included in training programs. Lifting instructions are only a small part of total effective injury prevention; proper sitting, standing, pushing, pulling, and turning procedures must also be included. The blue collar worker can and will take responsibility for his or her own back care with proper training.

INTRODUCTION

Second only to the common cold, back injuries and back pain are the most frequent problem in the work force in the United States. Over 75 pct of the population suffers from back pain at some point in time. Back pain interferes with worklife and social habits. In 1980, it accounted for 93 million lost-time days, as well as $5 billion in medical costs and $12 billion in legal and insurance fees (11).[2] These figures have risen in the past 2 yrs. Back injuries may account for only 25 pct of all injuries, but cost over 65 pct of the dollars spent. Back pain and back injuries have become one of the most expensive health problems in the mining industry just like every other industry in the United States. Unfortunately, knowing that "everybody has it" does not alleviate the discomfort or the frustration that accompanies back pain.

DISCUSSION

Back injuries are frustrating because they are so difficult to identify, diagnose, and treat. Differentiation between a "real" injury and a "supposed" injury is challenging to the medical community as well as to industry. It is not the kind of injury that can be casted and be healed in a certain length of time (8). Back injuries become a problem of balance sheets and productivity versus worker's compensation premiums and lost-time days.

In the underground coal mining industry, an average of 2,500 back injuries per year occurred between 1977 and 1981. If the average cost of a back injury is $5,000, a yearly expenditure could be over $12 million. Of course, not all back injuries cost $5,000, but some cost much more (12). This figure does not include those individuals who undergo surgery or have long-term problems.

Since back injuries are a fact of life, a safety director or personnel manager with safety-related duties becomes an integral part of the team that tries to oversee the problems. Unfortunately, that individual is usually consumed with paperwork and has neither the time nor budget to initiate an effective program. So he or she turns the entire dilemma over to the supervisors. Supervisors may be very knowledgeable about mines and mining, techniques and equipment, but they rarely have experience in safety and injury prevention. Yet, they are the people who are made ultimately responsible for every back injury on the job. There is no way they can stop the back

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[1]Director, Spine Education Center, Dallas, TX.

[2]Underlined numbers in parentheses refer to items in the list of references at the end of this paper.

pain problem unless they have adequate training and management's support (15).

It is not unusual for a typical safety program to allocate 0.04 pct of an entire budget to safety, which translates to $50,000 if the company has a yearly operating budget of $130 million (3). It is definitely time to modify the present system. Back injuries alone represent a costly liability. Training techniques must also be modified to stimulate the individuals who are doing the work. We must remember that all of us are much more highly educated and exposed through the television media than we once were. The American worker expects and should receive training that is relevant to his or her situation.

The concept of educating individuals to be responsible for their own health care has surfaced in recent years. Extensive studies have determined that education has been the key factor in helping hemophiliacs and diabetics control their diseases successfully (13). People with back pain have not had much information available to them, so they have been unable to control their problems. Back education and "back school" began in Sweden in 1970. In a triple blind study, there was substantial evidence indicating that education returned patients to work sooner than regular physical therapy modalities (1). Also, recurring absence from work was reduced.

The group incurring back injuries are those individuals who are doing the actual labor, not the supervisors. Therefore, it is important that the workers be trained using appropriate techniques and materials. Supervisor participation and management support is essential for effective results. If given applicable information, miners will be able to take responsibility for their own back care.

The program content found to be most effective is a comprehensive one that consists of information that incorporates several topics as they relate to the person working in a mine and their potential back problems.

People cannot be expected to take care of their back unless they have some understanding of anatomy (8). We have a spine for two reasons; one is for support. The other function of the spine is to protect the spinal cord.

We have a number of anatomical parts that affect the way we feel, but the most common long-term injury involves the disks. Disks rest between the 24 vertebrae in our backs. Disks are the shock absorbers of our bodies, just like we have shock absorbers in our cars. An effective training program will use analogies that are easily understood. For example, disks look a lot like a jelly doughnut; crusty on the outside with jelly on the inside. And everyone understands what happens if a jelly doughnut is crushed; it leaks, just like a disk does when it is crushed. Unfortunately, when a disk herniates, that jelly may interfere with the nerves and cause pain and neurological deficits that will lead to surgery. A ruptured or herniated disk is the most common reason for back surgery.

If we are interested in avoiding disk herniation, it is necessary to understand disk pressure. Different body positions put more or less pressure on the low back area; extensive studies from Sweden have demonstrated this. For example, a person who stands with knees locked, bent forward, will put 200 lb of pressure on the low back area (fig. 1). An individual who sits incorrectly will do the same thing. However, if we can reeducate that person to sit with arms and back supported and knees higher than hips, we can cut that disk pressure in half. When lifting, a person who holds material a forearm's length away from his or her body will put 10 times more pressure on the low back than if that same object is held close. Fortunately we can put ourselves in positions that are comfortable as well as beneficial. Lying on your back with your feet on a stool puts only 25 lb of pressure on the low back (fig. 2). For this reason, it is called the resting position (7).

Pressure on the back is directly related to body mechanics (6). Body mechanics is not just lifting. It is sitting, standing, bending, stooping, reaching, and turning, as well as lifting. In employee training, a giant inadequacy has been the neglect to educate the worker about job-related situations other than lifting.

For example, there are two tribes in the world that have no incidence of back pain: One is in Mexico, and one is in Africa. Apparently, they do not have back pain because they do not spend much time sitting. Everyone in this country spends a great deal of time sitting, whether at their job or at home watching television, and that is contributing to the back pain problem (11).

We know that absorption of information is directly related to understanding the subject matter presented (10, 14). Obviously then, a back injury prevention program for miners should utilize visuals of miners in their job situation.

Sitting with knees higher than hips takes pressure off the back in situations that require sitting. Getting close to the worksite and working straight ahead takes pressure off the low back area. Getting down to the level of the work is as important as staying close when reaching. However, miners have a difficult problem because they are forced to stay in that position for long periods of time (12). Protecting their backs may contribute to knee problems.

Standing with knees locked may not cause a back injury, but it can give you a very tired back by the end of the day. It is recommended that a person who stands all day put one foot slightly in front of the other with knees slightly bent. This gives the individual a wider base of support so that the back is not as likely to be stressed. If a piece of equipment is available, putting one foot up will take even more pressure off the back. Bars have railings for back comfort while standing and drinking.

Ergonomics plays an important role in back injury prevention (6). Look for simple modifications to install to make employees more comfortable.

Other body mechanics techniques that should be discussed are pushing, pulling, lifting, and pivoting. Pushing is usually more desirable than pulling. An accident that occurs with frequency is pulling with feet parallel--an individual using only his or her back--and a mechanical device close by.

Lifting, like other jobs, can be done in several ways. The person handling material should be as close as possible to the object. This is the most important concept. Lifting can be accomplished by putting one knee down or squatting. It is important that the legs be used for leverage, not the back (fig. 3). Not everyone can lift the same way. People and material come in different sizes and should be handled accordingly. These different options should be demonstrated, discussed, and practiced at the time of training. Learning to pivot rather than twist is particularly helpful.

Employees need to know how to modify their body mechanics and why. It is important that employees understand the benefits of using good body mechanics and the disadvantages if they do not. With this knowledge, they can think about a job, their back, and the best way to avoid pressure when performing that job (8). Utilizing mechanical devices whenever possible will also diminish injuries.

Injuries occur at home, too, and because of our system, they may become a Monday morning worker's compensation accident. Therefore, it is important for the miners to be able to transfer these new techniques to a home situation. Even shaving and brushing teeth can cause back pain. An alternative is to bend the knees into the sink or put a foot up in the cabinet. Doing yard work incorrectly can cause back pain; driving long distances in the car can, too. Most Americans drive with the seat too far away with knees dropped below hip level.

Moving the seat forward a notch may alleviate the problem. An inexpensive back support can be created by rolling up a towel. There are also two-person jobs at home, and it is important that safe techniques be practiced off the job.

Considering that the majority of the population has back pain some time in their life, it is sensible to give everyone a workable first aid treatment for back pain. Most people suffer from back pain that involves muscle spasm. The most effective treatment found is ice massage, stretching, and the use of aspirin. Muscles that are tight and tense are in spasm. Ice massage will numb the area and allow the knees to be brought up toward the chest to stretch those muscles out to their normal limits (4, 9). Muscles only have the capability to contract by themselves. If you have ever experienced a cramp in the foot in the middle of the night, you know you have to walk on it or rub it. Muscles in the back are like that. They have to be stretched to their normal limits. The use of ice will allow that to occur. Aspirin is a superb anti-inflammatory and will help control pain.

Men and women who have ulcers or bleeding problems should not take aspirin, but most people can take aspirin several times a day as long as they drink plenty of fluids. Directions should be included with the general information given to the employees at training.

It has been determined that for every day a person is immobile, it takes 4 days to rehabilitate that individual to normal function. Therefore, mobility is important. Light duty will prevent the employee from behavioral changes. Furthermore, a person who is at bedrest for several weeks becomes weak and is very likely to have an injury the first day on the job since theri muscle tone is poor. Maintenance of muscle strength is very critical when the worker must return to a job situation (8). Although the majority of the injured miners reported in the underground coal mining statistics returned to the job in 3 weeks or less, it is important to consider the rapidity of the deterioration of strength if a miner has been in bed for several days. Physical fitness affects the occurrence of back injuries, so the injured employees should be given instructions in strengthening and stretching exercises and should be encouraged to do these before returning to work (2).

It follows, therefore, that the person who is in poor physical condition may have weight and posture problems and could be a candidate for an injury. Stress may also affect the back, causing muscles to tighten which may lead to muscle spasm. A physical fitness program may diminish many of these problems.

In November 1982, two psychologists from North Texas State University conducted a study involving eight industries and approximately 1,500 employees. One hour of back injury prevention education was provided to the employees of these industries. The programs were given in small groups at the jobsites and were customized for the specific industry and their needs. Companies participating in the evaluation were representative of both light and heavy industry. Both safety directors and participants were asked to respond. The employee response was a random sampling. The results were as follows: Safety directors report a 40-pct reduction in lost-time days the year following the presentation with a decrease in medical insurance expenses in three of the companies. There was an increase in numbers of reported injuries, but those participating in the program reported fewer injuries. The participants reported an 86-pct decrease in lost-time days and a 63-pct reduction in injuries. Lawlis and Hennig (5) reasoned that the reported increase in back injuries was primarily due to the changes of management's perception of back injuries and the employees' willingness to report early injury and accept early treatment. The large reduction in lost time would support that premise.

Although each program was customized, all employees received the same format of information. Followup material included posters that were placed in common areas

and reminder cards placed in paychecks 6 months following the program. A short refresher course was offered 1 yr following the initial presentation.

CONCLUSIONS

Back injuries are a major health problem in the United States, but can be prevented and controlled through education and training if the material is designed for the person on the job. It must be informative, interesting, fast-moving, and relative. Body mechanics concepts must be emphasized in different ways so the individual can adopt the positions that work best for his or her situation both at work and at home (14). Use of the first aid treatment should be encouraged at the first sign of back strain. Light-duty programs should be initiated to keep the individual mobile and in touch with his peers and management. Practical demonstration is important, but actual participation in sitting, standing, lifting, and pivoting procedures is essential. The trainer must be well-prepared before the employee can be expected to retain the information presented. Followup is a mandatory part of any safety program. If employees are given appropriate information, they can and will take responsibility for their own back health care (13).

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FIGURE 1. - This position will put 200 lb of pressure on the back.

FIGURE 2. - Position showing only 25 lb of pressure on the low back.

FIGURE 3. - Legs should be used for leverage, not the back.

A MANUAL MATERIALS HANDLING (MMH) TRAINING PROGRAM FOR THE MINING INDUSTRY

By Daniel J. Connelly[1]

ABSTRACT

Back injuries have been a continuous and increasing problem in the mining industry. Accident statistics reveal that most back injuries occur during manual materials handling activities. Various methods have been attempted to control these accidents. Training in safe materials handling is one approach that has been used over the years. This paper provides a number of general recommendations and specific examples to assist training personnel in the mining industry to develop a manual materials handling training course to reduce back injuries.

INTRODUCTION

Back injuries have been a continuous and increasing problem in the mining industry (table 1). In coal mining, for example, approximately 20 pct of all injuries are back injuries. Consequently, a significant percentage of the total nonfatal lost workdays are due to back injuries (table 2). Likewise, the costs of back injuries to the mining industry are significant.

A review of accident statistics show the majority of back injuries reported by the mining industry are the result of materials handling accidents (table 3). The accident classification, handling materials, is defined as an accident related to handling packaged or loose material while lifting, pulling, pushing, or shoveling (10).[2]

Miners involved in materials handling activities, whether underground or on the surface, are exposed to a number of potential accident situations. Many factors contribute to the hazards of materials handling. The major components are the worker, the task, the materials handled, and the work environment. If materials are not handled properly, the result can be a lost-time injury, most likely occurring to the back.

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[2]Underlined numbers in parentheses refer to items in the list of references at the end of this paper.

TABLE 1. - Total injuries, back injuries, and percentage of back injuries at coal, metal, and nonmetal mines in the United States, 1978-80 (10-12)

	1978	1979	1980	1981
Coal mines:				
Total injuries.................	20,203	23,677	22,723	18,821
Back injuries..................	3,762	4,948	5,111	4,119
Back injuries.............pct..	18.6	2.9	22.5	21.9
Metal mines:				
Total injuries.................	8,713	9,619	8,028	7,570
Back injuries..................	1,247	1,428	1,246	1,153
Back injuries.............pct..	14.3	14.8	15.5	15.2
Nonmetal mines:				
Total injuries.................	3,844	3,497	3,066	2,697
Back injuries..................	664	608	607	461
Back injuries.............pct..	17.3	17.4	19.8	17.1

TABLE 2. - Total nonfatal lost workdays, nonfatal lost workdays due to back injuries and percentage at coal, metal and nonmetal mines in the United States 1978-80 (1-3)

	1978	1979	1980	1981
Coal mines:				
Total NFDL.................	494,464	662,704	662,911	616,342
NFDL-back injuries.........	113,817	155,583	193,806	176,065
Back injuries.........pct..	23.0	23.5	29.2	28.6
Metal mines:				
Total NFDL.................	148,034	187,092	179,081	149,510
NFDL-back injuries.........	21,481	27,428	40,932	25,049
Back injuries.........pct..	14.5	14.7	22.9	16.8
Nonmetal mines:				
Total NFDL.................	78,146	75,053	58,363	58,,218
NFDL-back injuries.........	11,667	15,557	11,699	10,521
Back injuries.........pct..	14.9	20.7	20.0	18.1

NFDL Nonfatal days lost.

TABLE 3. - Total back injuries, materials handling[1] back injuries, and percentage at coal, metal, and nonmetal mines in the United States 1978-80 (10-12)

	1978	1979	1980	1981
Coal mines:				
Back injuries..............	3,762	4,948	5,111	4,119
Materials handling back injuries..................	2,139	2,932	3,008	2,427
Back injuries.........pct..	56.9	59.3	58.9	58.9
Metal mines:				
Back injuries..............	1,247	1,428	1,246	1,153
Materials handling back injuries..................	636	749	654	597
Back injuries.........pct..	51.0	52.5	52.5	51.8
Nonmetal mines:				
Back injuries..............	664	608	607	461
Materials handling back injuries..................	380	386	375	271
Back injuries.........pct..	57.2	63.5	61.8	58.8

[1]Handling materials accidents are defined as accidents related to handling packaged or loose material while lifting, pulling, pushing, or shoveling.

In addition to back injuries, there are other types of injuries associated with materials handling accidents. These other injuries, such as bruises and cuts of the fingers and hands, account for a minor percentage of the total costs of injuries arising from materials handling.

WHAT CAN BE DONE?

In many mining companies, frustrations over the seemingly insoluble back injury and materials handling problems create attitudes that further aggravate the problems. Several positive steps can be taken to control the hazards. Traditionally, the prevention of back injuries has been attempted by

1. Careful selection and placement of workers.

2. Training in safe lifting.

3. Designing the job to fit the worker (7).

Training for manual materials handling in the mining industry is the main topic of this paper. Training in safe handling methods alone will not solve the back injury problem. The problems of back injuries and materials handling are multidimensional in nature. Training is only one approach that should be used in combination with other control methods, such as job redesign, and worker selection and placement (1).

TRAINING TO CHANGE BEHAVIOR

The ultimate objective of any training program is to change behavior of people. That is, to cause them to do their jobs effectively and correctly (i.e., safely). However, there are many factors that influence human behavior on the job. Behavioral change can be insensitive to training if other factors (i.e., environmental, managerial, physiological, social, etc.) predominate in determining the way people are behaving (6). Therefore, training can be identified as one of many variables to consider and control to achieve behavioral change.

TRAINING TO REDUCE BACK INJURIES

Training for the purpose of reducing back injuries has been conducted throughout industry for many years. Even though, few in-depth studies have been made to determine the effectiveness of lifting and materials handling training (8, p. 176).

The importance of training in manual materials handling (MMH), however, has been generally accepted, and is likely to continue. What is needed is a clear definition of what the training should be and how it should be taught. The only general criteria would appear to be that training should involve the worker actively in the learning process and identify specific techniques and hazards of MMH tasks (8, p. 199).

A MODEL MANUAL MATERIALS HANDLING TRAINING COURSE

The National Institute for Occupational Safety and Health (NIOSH) publication, "Work Practices Guide for Manual Lifting," provides recommendations regarding the training of workers who perform MMH tasks (9, pp. 99-101). These recommendations form the basis for a model MMH training course. The aims of safety training in MMH should be to--

1. Make the miners aware of the dangers in MMH.

2. Show miners how to avoid unnecessary stress.

3. Teach miners individually to be aware of what they can handle safely.

The following items should be covered in the training course:

1. The risks in manual materials handling. Based upon the materials commonly handled and the accident history of the mine.

2. The basic principles of manual materials handling. The basic physics of MMH, the body as a system of levers, and the work needed to shift loads.

3. The effects of MMH. The basic anatomy of the back, muscles, and joints, and the effect of lifting on the body.

4. Individual awareness of the body's strengths and weaknesses. Teach miners how to judge the weights they can handle safely, and where their body strengths and weaknesses lie.

5. How to avoid accidents. Teach miners how to recognize and avoid the physical factors that might contribute to an accident, for example,

a. Is the load free to move and not stuck?

b. Is it a weight that can be safely handled by one person?

c. Are lifting aids available?

d. Does the load have handles to grasp or can they be provided?

e. Is protective clothing needed?

f. Is the work area clear of obstruction?

g. Is the floor clean, dry, and nonslip?

h. Is the area clear where the load will be set down?

6. Handling skill: Emphasize the actual materials handled at the mine. Provide instruction on the following general points:

a. How to prepare for materials handling tasks.

b. How to recognize what loads can be handled safely.

c. How to keep the load close to the body when lifting.

d. How to lift without twisting or bending sideways

e. How to use the legs to get close to the load and to make use of the body weight and the kinetic energy of the body and load.

f. How to develop timing for smooth and easy lifting.

7. Handling aids: Demonstrate the handling aids available for materials handling tasks, and encourage their use.

DETERMINING MATERIALS HANDLING TRAINING NEEDS

The basic steps of training in general apply equally well to the training of miners for materials handling tasks. In order to develop an effective training program, identify and define the materials handling problems and then establish procedures to control those problems.

Information necessary to evaluate materials handling includes accident records, mine conditions, and discussions with mine personnel. An accident analysis will identify problem areas, in terms of the who, what, where, how, and why (individuals, tasks, materials handled, causes, and so forth). This information will provide a good idea of what areas or topics need to be emphasized during training (3).

In addition to the basic information about accidents, obtain specific details concerning mine policies, procedures, equipment and supplies, and responsibilities of the miners. Obtaining this information will require talking to the mine personnel most familiar with the day-to-day operation of the mine, the section supervisors. Questions should cover the problems and hazards of materials handling activities at the mine or sections of the mine.

HAZARDS OF MATERIALS HANDLING IN THE MINING INDUSTRY

Accident analyses of materials handling accidents have identified several potentially hazardous tasks (5). Most of these accidents involve the act of manually handling materials, specifically, lifting and lowering, pushing and pulling, carrying, and shoveling. Although these accidents provide an indication of the general hazards of materials handling, training should concern specific tasks and materials associated with the problem areas.

Understandably, the underground mine environment is more hazardous and more difficult to work in than most surface environments. Underground conditions increase the potential for accidents. For example, poor maintenance of the mine floor results in slippery and uneven footing which contributes to accidents. Bending or sitting on folded legs is common in mines of low roof height. Lifting or carrying materials under such conditions can result in back injuries (4). In addition, the weight of materials handled sometimes exceeds the physical capability of the miner and this can result in injury. It is for these reasons that training in materials handling should include discussions of the work environment and the physical limitations of the workers.

TRAINING METHODS

Lecturing requires that the instructor talks and the miners listen. While this method can be effective for a short period of time, it should not be the only method used. A short lecture on the basic structure of the back, for example, should be combined with slides or films and class discussion. A discussion allows for class participation. Asking a few questions helps to focus on the topics you want to cover. The following examples are questions that can be used for discussion:

1. What are the most common injuries and accidents in the mining industry and at your mine?

2. What are the most common materials handling accidents?

3. Where in your mine are materials handling accidents occurring? And to whom?

4. How can these accidents be prevented?

Demonstration is the best teaching method to use to show how something is done. The classes should be small enough that safe materials handling methods can be demonstrated, preferably at the worksite. The materials or objects known to be associated with materials handling accidents and back injuries (such as trailing cables, oil drums, roof bolts, timbers, rock dust bags, etc.), should be used in actual demonstrations.

Mine supervisors should be actively involved in developing and conducting the training course. It does little good to train miners in safe handling methods if the methods are not used during materials handling tasks on the job. Therefore, observing day-to-day job performance and correcting unsafe acts are essential responsibilities of the mine supervisors.

COURSE OBJECTIVES

The purpose of the course should be to instruct miners in the safe methods of materials handling. After completion of the course, the miners should be able to identify the following:

The basic anatomy of the back.

General safety rules.

Safe lifting method.

Safe carrying method.

Safe shoveling method.

The miners should be given a test to demonstrate they have learned the material. The test method should provide evidence, either by doing or by listing the safe methods, that the miners have learned what you want them to do.

COURSE MATERIALS

The following illustrations provide examples of course materials for training in materials handling.

A brief lecture on the basic anatomy of the back can be used to teach the effects of materials handling on the body. Figure 1 shows the structure of the back (2). The NIOSH publication, "Work Practices Guide for Manual Lifting," provides reference material that can be helpful (9).

Discussions of personal experiences with back pain can assist in "selling" the need for the training. Examples of materials handling accidents at your mine "bring home" the point that the potential for injury is real. Analysis of your mine's accident history can reveal the problem areas that need to be emphasized. Figure 2 illustrates typical examples of materials handling accidents.

Strains, bruises, cuts, or other injuries may result from handling materials. Personal protection equipment and reasons for wearing them should be covered during the training course. Figure 3 shows the personal protective equipment that should be worn (2).

Lifting and lowering materials are the most common materials handling tasks performed in the mines. Figure 4 provides examples of safe lifting methods. The lifting tasks selected for your training course should include the materials most often handled at your mine.

Accident statistics show that handling electrical cable is a leading cause of back injuries and materials handling accidents in mining. Many of these accidents result from the miner pulling on the cable rather than lifting. Figure 5 provides instruction on the safe handling of cable.

Shoveling coal and rock account for a large number of back injuries in mining. Therefore, instruction provided on the safe method for shoveling materials is needed as shown in figure 6 (2). The main point to stress is to avoid twisting the back while shoveling.

GENERAL MATERIALS HANDLING SAFETY RULES

There are a number of general safety rules that apply to materials handling. One of the most important is to plan ahead. Determine where the material will be placed before moving it. If carrying materials a long distance, plan rest stops to prevent fatigue. If the material required to be moved is too heavy, then get help or use a mechanical device, such as a hoist, wheelbarrow, front-end loader, or forklift. The miner should also be instructed to become aware of the surrounding environment, obstacles in the pathways, and wet or muddy floor surfaces.

SUMMARY

Back injuries have been identified as a significant problem area in the mining industry. Accident statistics have shown that most back injuries occur during materials handling activities. Training in safe materials handling methods is one approach for control of back injuries. A number of general recommendations and specific examples have been presented to assist training personnel in the mining industry to develop a manual materials handling training course to reduce back injuries. It is hoped that some practical suggestions have been made and will be used where needed in the mining industry.

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Your back is a "complex system"

It includes:

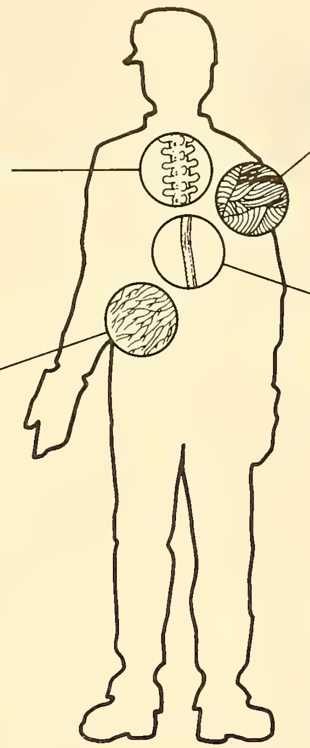


FIGURE 1. - Basic anatomy of the back.

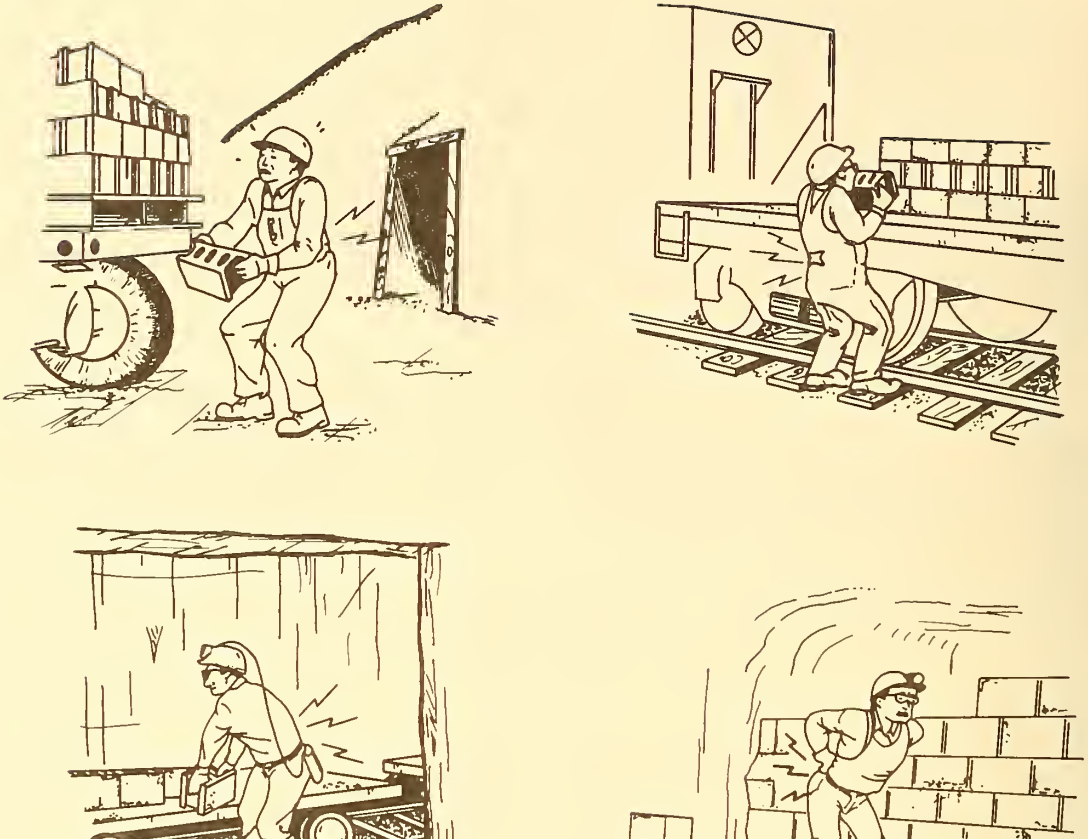


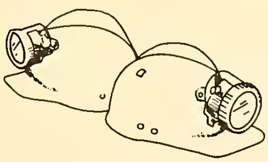
FIGURE 2. - Examples of materials handling accidents.

METATARSAL SHOES

Injuries to the feet are common and painful. They most frequently occur when materials that are being carried slip or when they fall because they are stacked improperly. Metatarsal shoes are recommended because they protect your entire foot.... the toes, the arch, and the top.

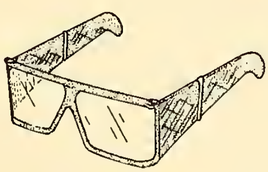
HARD HATS

It is easy to bump your head against overhead obstacles or stacked supplies while working in congested, dark surroundings. Hard hats are essential for your protection and should be worn at all times.....whether you're working outside or inside the mine.



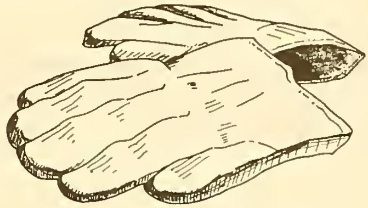
SAFETY GLASSES

Your eyes should be protected from coal dust, rock dust and other particles that can cause severe irritations. Safety glasses make sure such damaging abrasives do not enter your eyes.



LEATHER GLOVES

When handling materials and supplies, it is important to maintain a firm grip. Leather gloves help you to do this, as well as protecting your hands from cuts, burns, and blisters that could become infected.



RUBBER BOOTS

Since you will be working around high voltage trolley wires and wet, muddy areas it may be necessary to wear rubber boots to avoid any electrical shock. Rubber boots also help you maintain a firm foothold.

LEG BANDS

Securing your pants legs is an essential part of your safety. Leg bands is one way of doing this. You should wear them at all times to avoid tripping and getting caught on moving pieces of equipment.

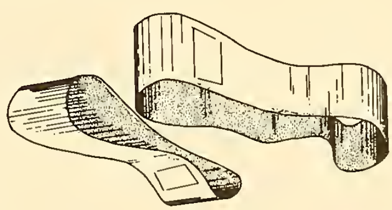
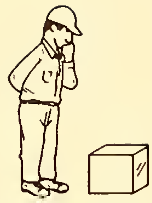


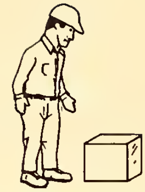
FIGURE 3. - Personal protective equipment.

A



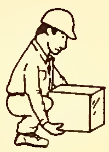
A

As you approach the load determine its weight, size and shape. Consider your physical ability.



B

Stand close to the object with feet 8 to 12 inches apart for good balance.

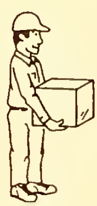


C

Bend the knees and get a firm grasp on the object.

D

Using both leg and back muscles lift the load straight up. Keep the object close to the body.

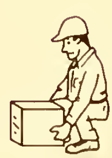


E

Do not twist or turn until the object is in carrying position.

F

Rotate body by turning your feet and make sure path of travel is clear.



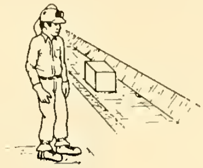
G

To set the object down, use leg and back muscles and lower the object by bending the knees.

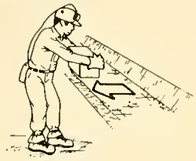
FIGURE 4. - Safe lifting. *A*, From the floor.

B

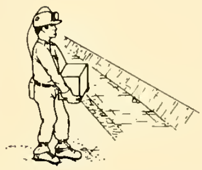
A. First, stond close to the belt ond estoblish firm footing.



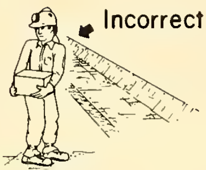
B. Then get the items to the side of the belt by pulling groduolly, without sudden jerky movements.



C. Lift the items off the belt, keeping your bock os stroight os possible ond holding the lood close to your body.



D. Remember not to twist your bock when unlooding moteriols, os this miner is doing. Insteod, reposition your feet, ond turn your body.

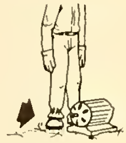


E. Then bend your knees to lower the lood.

C

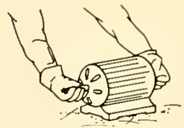
A. First, be sure to wipe off ony dirt or greose before reaching for the ob-ject you are going to lift.

B. Then, stand close ta the object and get a firm foothold.



C. Stroddle the load somewhat and squat dawn, bending at the knees ...... not at the back.

D. Hald the object securely so your grosp does not slip.



E. Finally....slowly straighten to an up-right stance, keeping your back in a verticol position.

FIGURE 4. - Safe lifting.—Continued. *B*, From a belt; *C*, an irregular shaped object.

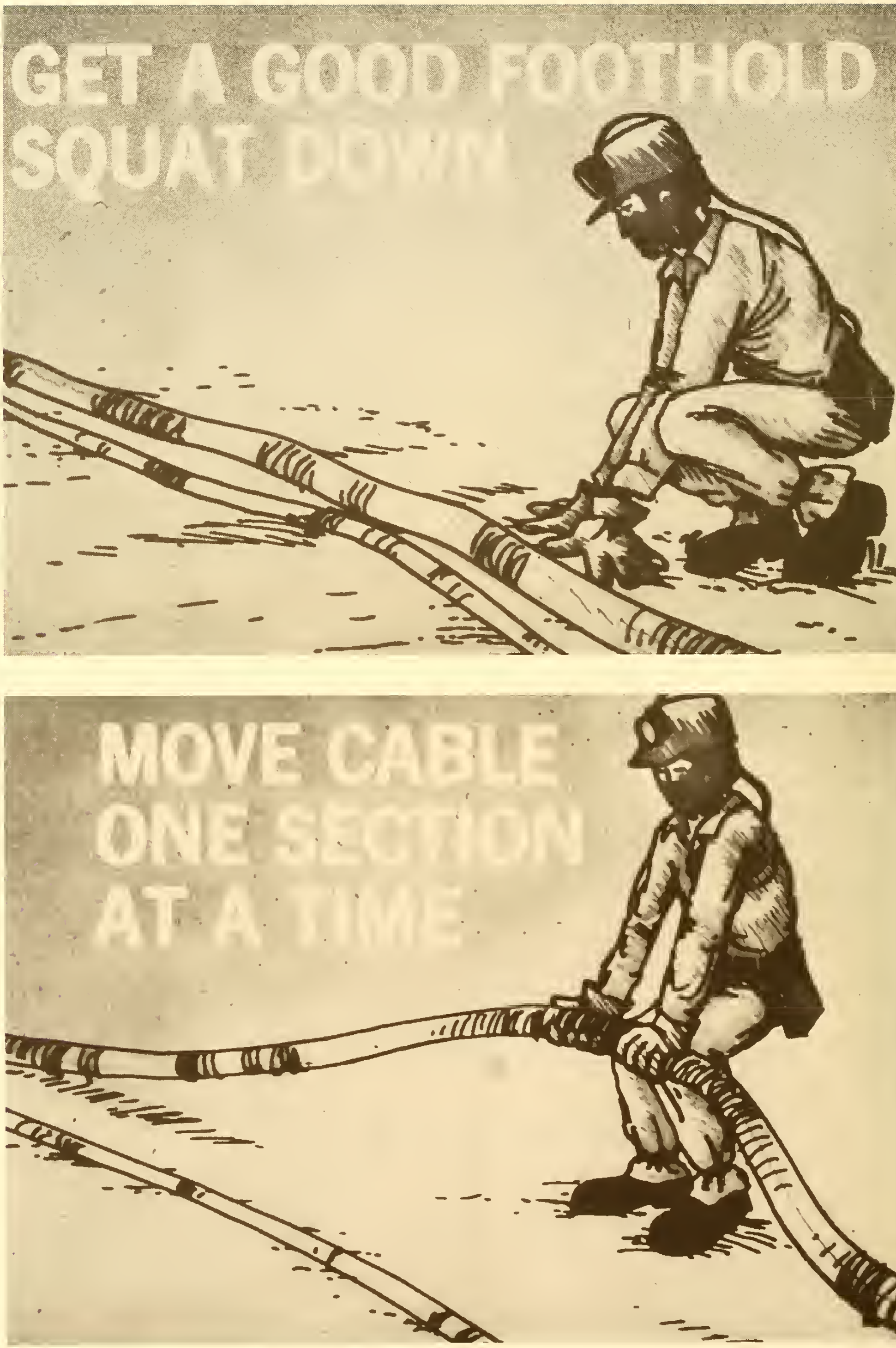
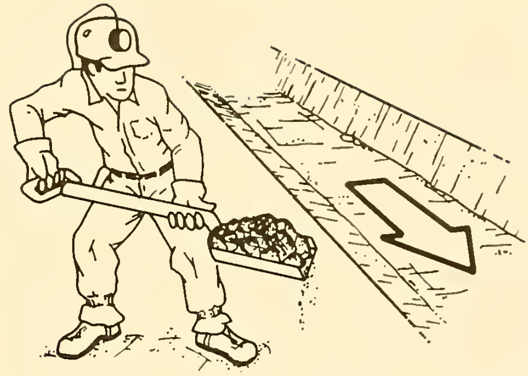


FIGURE 5. - Handling cable.

Always shovel in the direction the belt is moving. This way, you avoid catching the shovel in the belt and keep from getting hit with the handle.



Avoid twisting your back. Turn your feet and your entire body so your back is not strained.

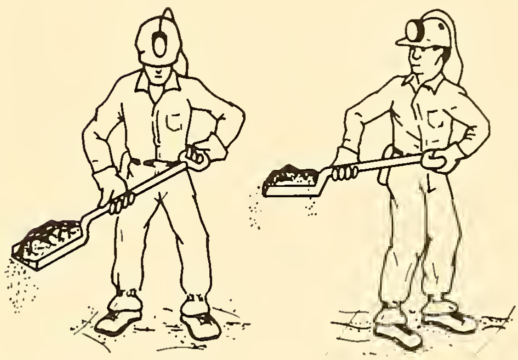


FIGURE 6. - Example of safe shoveling.

MECHANIZATION OF MATERIALS HANDLING TASKS

By Richard L. Unger[1]

ABSTRACT

The Bureau of Mines is sponsoring research aimed at reducing the manual effort required to transport or transfer materials used in underground coal mines. Specifically, production supply, mine maintenance, and equipment maintenance materials handling activities are discussed. A daily supply handling system is presented, as well as several concepts to reduce manual handling requirements during equipment and mine maintenance.

INTRODUCTION

In the mid-1970's, the Bureau of Mines sponsored studies to determine the types and causes of materials handling injuries in underground coal mines. One result of this work was the determination that approximately one-half of all materials handling accidents occur in the production supply function (fig. 1). Production supply refers to the handling of daily supply items from the surface to locations near the working face in support of production activities. Examples of this type of handling include transporting rock dust bags, roof bolts, and timbers. It was also found that the combination of equipment and mine maintenance functions accounted for approximately one-quarter of the materials handling accidents. Some examples of these functions include extracting motors from continuous miners, changing tires, and hanging cable.

The Bureau initiated two research projects to reduce the need for manual handling of items through a systems approach involving mechanization of supply handling. The first project, begun in 1978, was to develop a system for handling daily supplies in underground coal mines, directed primarily toward the production supply function. The second project was to develop a vehicle for mine and equipment maintenance activities. These two Bureau research projects were aimed at 75 pct of the materials handling accidents in underground coal mines. This paper describes the methods and results to date of these two projects.

A SYSTEMS APPROACH TO HANDLING DAILY SUPPLIES

The surest way to reduce materials handling injuries is to reduce or eliminate the need for manual handling. This is the purpose of the Bureau's daily supply handling system. Studies conducted at a Pennsylvania coal mine over a 2-yr span indicate that production times could be increased by at least 3 pct and supply handling injuries reduced by as much as 73 pct if a supply system based on palletization and mechanical handling were to be implemented. Such a system has been developed and is outlined below.

[1]Civil engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

PALLETIZATION

Daily supplies would be palletized on the surface and moved as unit loads throughout the mine. As much as possible, pallets of supplies as delivered by vendors would be moved to the section. The supplies moved to the section would be based on the estimated needs for that day. This should eliminate delay or lost production time owing to lack of materials or waste due to oversupply. Large items, such as timbers or rail, would be left on dedicated supply cars or trailers off the haulageway. These items are then off-loaded as needed. Empty pallets,

railcars, and trailers are returned to the surface on the return supply trip.

PERMISSIBLE FORKLIFT

Once the supply trip brings the pallets to the section, a method is required for off-loading and delivering them to the face as they are needed. After considering many alternatives, the Bureau chose the idea of a permissible, battery-powered forklift, with a winch and forks, for handling pallets and long narrow items such as timbers. An additional benefit would be using the forklift as a hoist to assist in equipment maintenance by reversing the forks. Figure 2 gives the forklift's specifications while figures 3 through 7 present its layout.[2] The forklift offers compactness, maneuverability and ease of materials handling underground. Forklifts are commonly used to handle supplies in the surface yard, however, the underground applications have usually been limited to high-seam mines that allow permissible diesel vehicles. This appears to be due to the unavailability of suitable forklift vehicles for use in the lower seams. Electric cable forklifts are available for underground use; but the cable restricts reach and maneuverability, thereby limiting its suitability for the section handling operations needed for this system[3] (fig. 8).

The forklift's task would be to unload the supply trip and move the pallets to the section storage area. As supplies are needed at the face, the forklift would deliver them pallet by pallet up to their point of use. The forklift's small size would enable it to manuever around most equipment in the entry, such as a roof bolter.

Rails, timber, and pipe are carried by a special sling attachment on the side of the forklift directly to the usage point (fig. 7). The forklift's operation generally requires two people: the operator and a helper who spots loads and directs pallet movement.

When not being used to handle supplies, the forklift has uses in equipment and mine maintenance activities. By reversing the forks, a hydraulically powered hoist is created that can remove or position heavy motors or lift timber to support the roof. It should be pointed out, however, that the main function of the forklift is supply handling. This differs from other vehicles sometimes used to handle supplies, such as a scoop. Often, when a scoop is needed to handle supplies, it is being used for its primary task of coal cleanup. The supplies must then be moved by other means, usually by hand.

TEST RESULTS

The daily supply handling system was tested at the Safety Research Coal Mine located at the Pittsburgh (PA) Research Center. Overall, the system worked well, with the need for manual handling of items reduced to the initial loading of the pallets and final use. However, there were problems, such as

Pallet design. Some wooden pallets could not withstand the rugged underground conditions, and broke apart after a short time in use.

A few lightweight-design steel pallets were tested and proved to be much sturdier. More testing is needed in this area.

The permissible forklift, though working well for a prototype, has a few deficiencies that need to be corrected. These include the need for increased traction in soft ground, greater overall battery life and speed, and more precise handling. The Bureau is considering a second prototype to correct these problems. An alternative solution would be for the mining industry or equipment manufacturer to apply their expertise in this area.

[2]Diaz, R. A., and A. D. Chitaley. System for Handling Supplies in Underground Coal Mines. BuMines contract H0188049; for inf., contact G. R. Bockosh, Pittsburgh Res. Center, Pittsburgh, PA.

[3]Work cited in footnote 2.

The palletization-forklift method of handling daily supplies in underground coal mines shows great promise for reducing manual materials handling. The results should be a reduction in materials handling injuries, more efficient distribution of supplies, as well as savings in daily supply handling labor.

MECHANICAL DEVICES FOR MINE MAINTENANCE AND EQUIPMENT MAINTNENACE

As stated earlier, production supply, mine maintenance, and equipment maintenance accounted for approximately 75 pct of materials handling accidents reported in Bureau's studies. The Bureau's work into a system for handling daily production supplies resulted in a palletization-forklift scheme. This section discusses the Bureau's project to reduce mine maintenance and equipment maintenance accidents.

The initial intent of this project was to design and develop a universal maintenance and materials handling vehicle. This approach has been tried before by the Bureau with poor results.[4] In a sense, the permissible forklift for the daily supply handling system is another attempt at an underground materials handling vehicle. However, there are two main differences between the forklift and the vehicle proposed for this project.

1. The forklift has one major task; transporting pallets. A maintenance materials handling vehicle, on the other hand, should be adaptable to individual tasks and be able to transport and position a variety of single items into all areas of the mine. This requires a versatile vehicle with several lifting and carrying attachments.

2. The forklift is intended to carry large volumes of items on a daily basis. A maintenance materials handling vehicle would be used only in specific situations, and therefore with less frequency. This would make the vehicle harder to justify in terms of cost.

[4]Foote, A. L., and J. S. Schaefer. Mine Minerals Handling Vehicle (MMHV) (contract H0242015, MB Associates). BuMines OFR 59-80, 1978, 308 pp.; NTIS PB 80-178890.

Based on the above reasons, it was decided that a series of simple, relatively inexpensive materials handling devices would be more readily accepted by mining industry. Each device would be tested in work situations at cooperating mines. The results of the tests, as well as plans and guidelines on fabrication, would be made available to the industry. The hope is that individual mining companies can be made aware of how mechanization of mine and equipment maintenance tasks can be both inexpensive and helpful in reducing their materials handling problems.

Eight materials handling device-tool concepts were generated, based on accident statistics, interviews with mine operators and underground mine visits. This lift was then reduced, due to budget constraints, to what was felt to be the five most useful devices. These devices are briefly described below.[5]

<u>Lifting Boom (fig. 9)</u>. One of the major needs identified was for a simple boom device that could be used to lift and transport components weighing up to 1 ton and to lower them safely to the ground. The boom would mount on the front of a small scoop when the bucket was removed, and would have a hydraulic winch with 100 ft of cable.

A device was built on this concept and is now in one of the demonstration mines for testing. All comments from the mine thus far have been favorable.

[5]Conway, E. J., and W. W. Elliot. Mine Maintenance Material Handling Vehicle: Investigative Study and Concept Development, BuMines contract H0113018; for inf., contact E. A. Ayres, Pittsburgh Res. Center, Pittsburgh, PA.

Mine Jack-Wheel Changer (fig. 10). Another concept is for a floor type jack that could be used to lift a component, transport it over short distances, and maneuver it into position for installation. Typical tasks would be aligning and lifting a drive motor under the fender of a shuttle car, or changing wheels weighing up to 1,000 lb on shuttle cars, cutters, etc.

The lift capability is derived from a hydraulic jack mechanism. The jack head tilts and rotates to allow more flexibility in placing the load. The ballon tires make movement easier over the mine floor, and the long handle provides leverage by which to maneuver the load up, down, or sideways as required.

Cable Puller (fig. 11). This device is a capstan powered by either a hydraulic or electrical source, and pulls a rope attached to a mining vehicle trailing cable. The pull rate can be controlled by the tension held by the laborer. The capstan can pull trailing cable and water hose out of an entry when preparing to move across the section or pull any cable on a conventional mining section.

Mud Truck (fig. 12). This device is designed for use in low-seam mines. It is equipped with high flotation tires to permit one person to pull it through soft bottoms. The steerable front tires and articulation joint provide even load distribution with maximum maneuverability. It can be used for transporting toolboxes, parts, and supplies to wherever they are needed.

Pivot Crane (fig. 13). This portable winch crane is an adaptation of devices commonly used on vehicles above ground. The crane mounts in a socket strategically located on any machine and can be stored at the section shop when not in use. Its uses include major component replacement in the 100- to 2,000-lb category or any lifting task adjacent to a machine.

All of these devices can be fabricated at the mine or in a small shop. Most can be modified to fit the needs of a particular mine. For instance, a chain winch can be substituted for the hydraulic winch in the lifting boom, at a substantial cost saving.

DISCUSSION

It is hoped that the mining industry will incorporate the ideas the Bureau is presently pursuing in relation to reducing materials handling accidents. Though every mine is unique, with its own particular materials handling problems, the ideas presented in this paper are adaptable to any mine in one form or another. It is up to the mine operator to make sure that avoidable materials handling accidents are eliminated by providing the most efficient methods of supply distribution as well as reasonable amounts of mechanization of materials handling tasks.

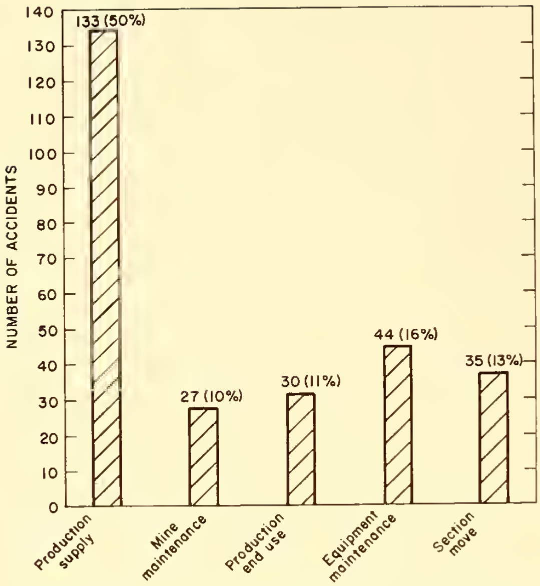


FIGURE 1. - Accident frequencies for different handling functions.

Permissibility	MSHA and Pennsylvania approved for work-face	
Type	Battery powered skid steer	
Drive	4 wheels driven by two hydraulic motors	
Payload	3- by 3-ft pallets typical at maximum 1,500 lb Timber 16 ft by 7 by 5 in, quantity 3 to 5	
Speed	1.3 mph maximum	
Range	2 h continuous duty	
Dimensions	Height	56-in over canopy
	Width	61 in
	Length	12 ft, 4 in
	Ground clearance	7, 9, or 11 in
	Forks	31-in long by 38 travel
	Empty weight	7,470 lb
Auxiliary equipment	Power winch	3,000-lb capacity 1/4-in-diam wire rope, 120 ft
	Timber carrying hooks	
	Reversible forks	
	Sheave and hook attachment for crane use of forks	

FIGURE 2. - The underground supply handling forklift specifications.

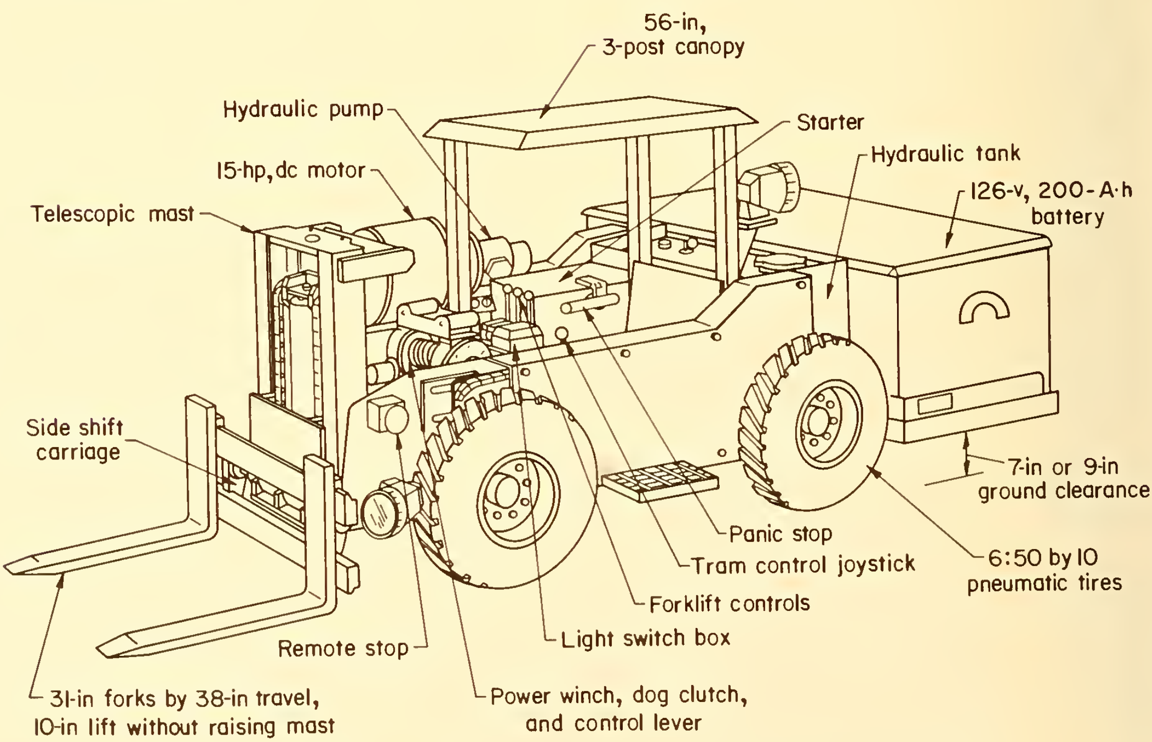


FIGURE 3. - Perspective schematic—underground supply handling forklift.

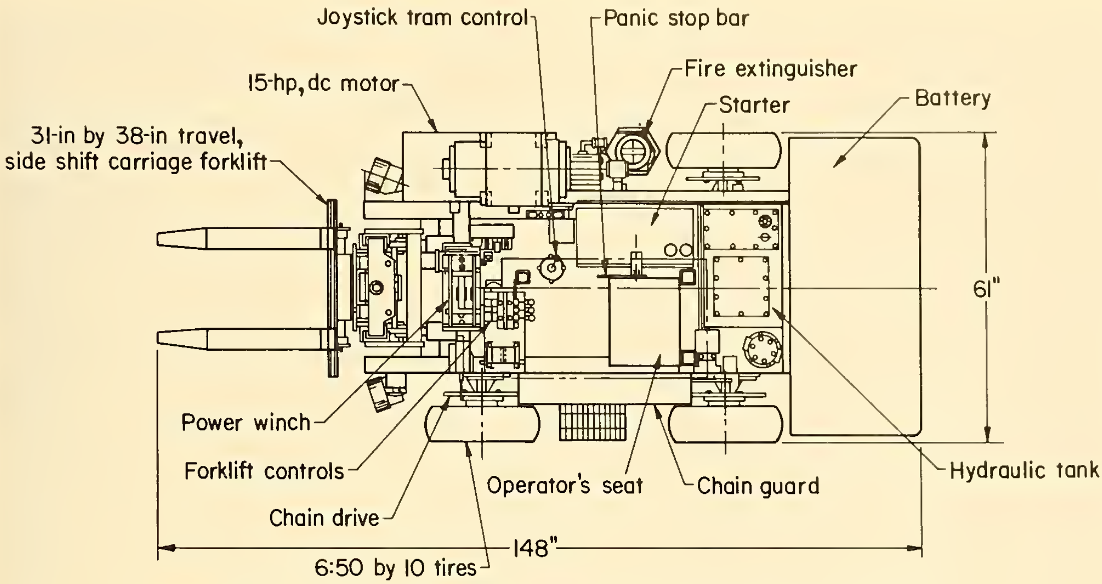


FIGURE 4. - Top view schematic—underground supply handling forklift.

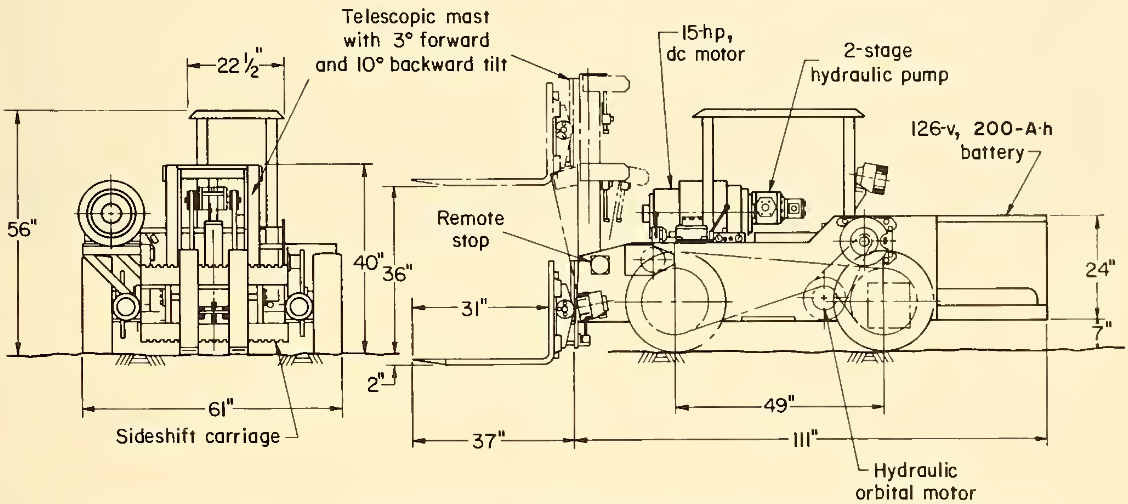


FIGURE 5. - Front and right side view schematics—underground supply handling forklift.

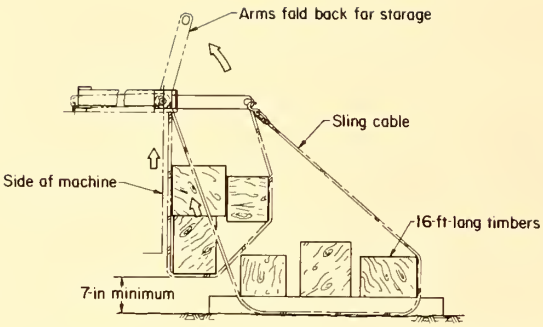


FIGURE 6. - Sling arrangement for carrying long, narrow loads.

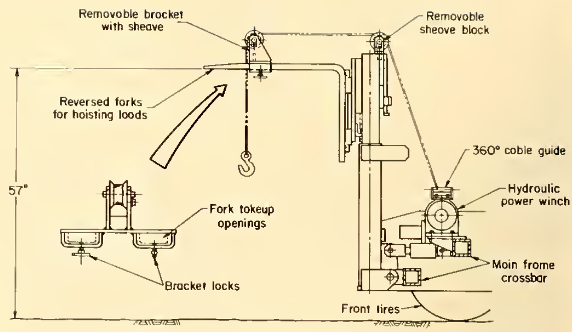


FIGURE 7. - Hoist configuration of forks.

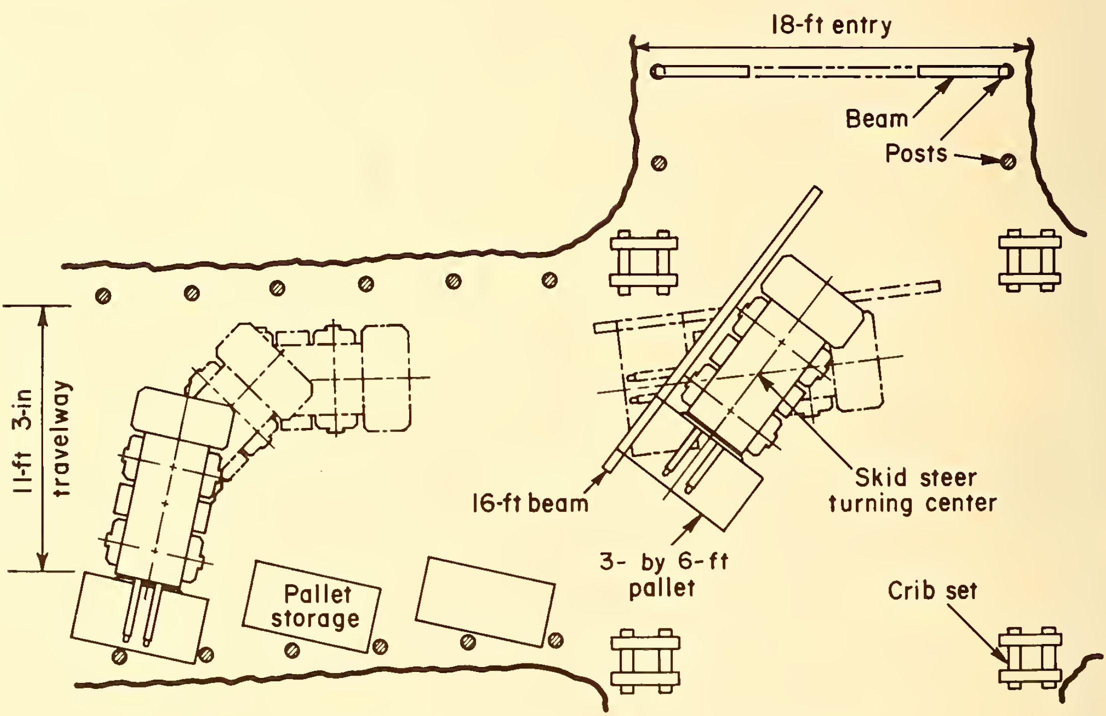


FIGURE 8. - Maneuvering capabilities of skid steer.

FIGURE 9. - Lifting boom during tests at a low-seam coal mine.

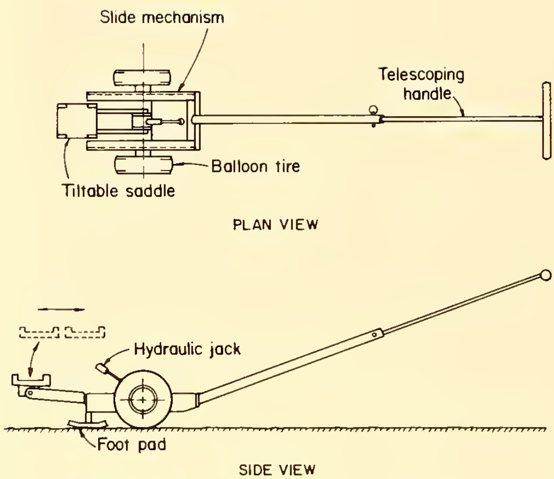


FIGURE 10. - Mine jack-wheel changer.

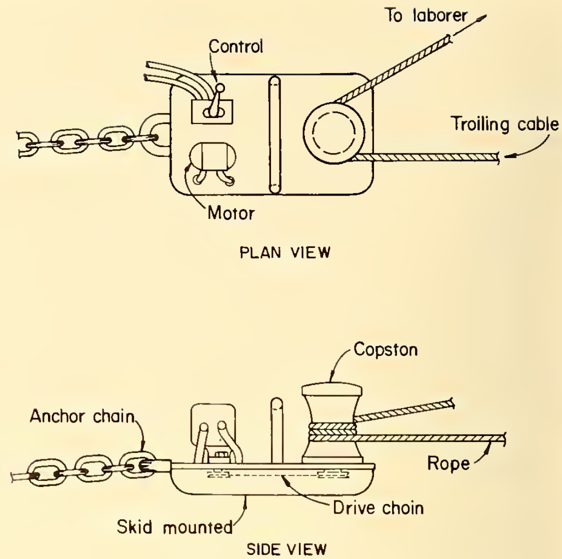


FIGURE 11. - Cable puller.

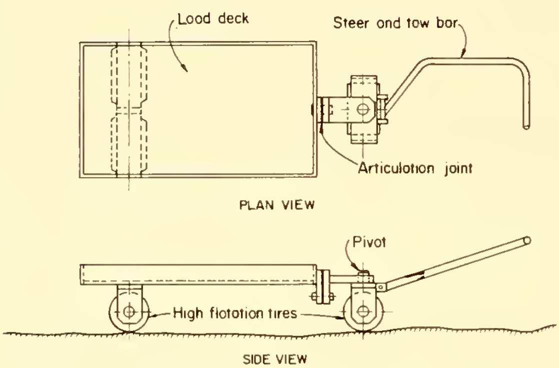


FIGURE 12. - Mud truck.

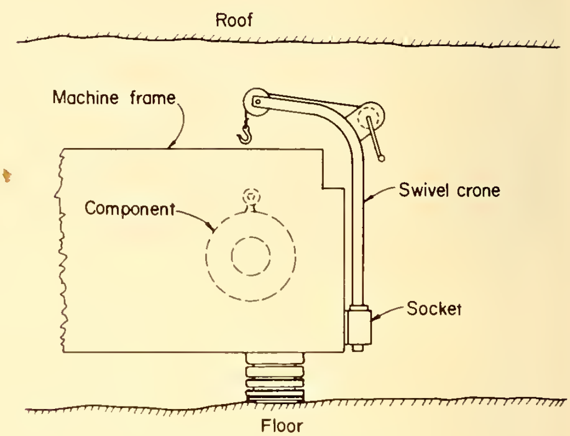


FIGURE 13. - Pivot crane.

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